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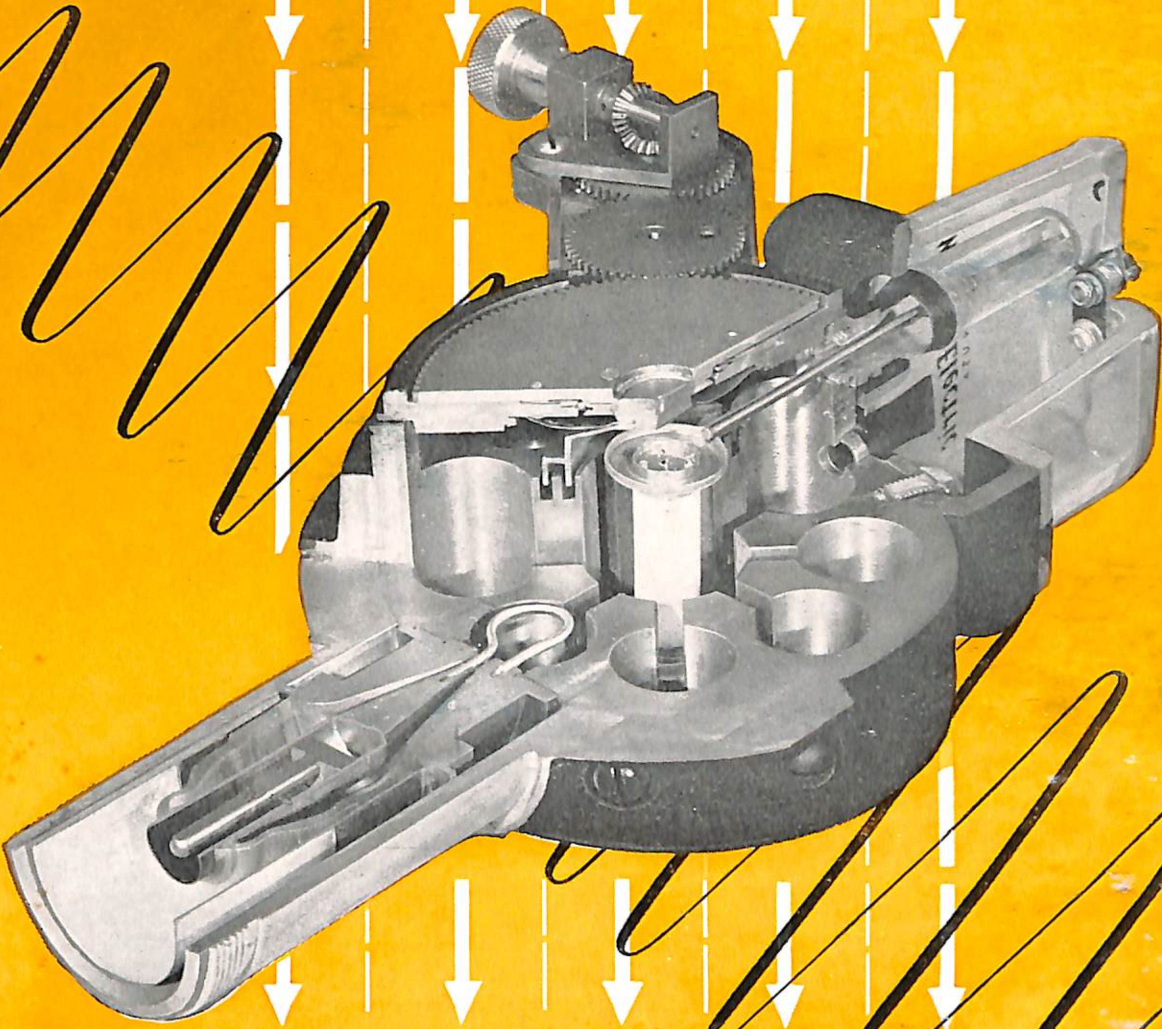
AUGUST 1946

BUSHIPS Electron



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BUSHIPS Electron

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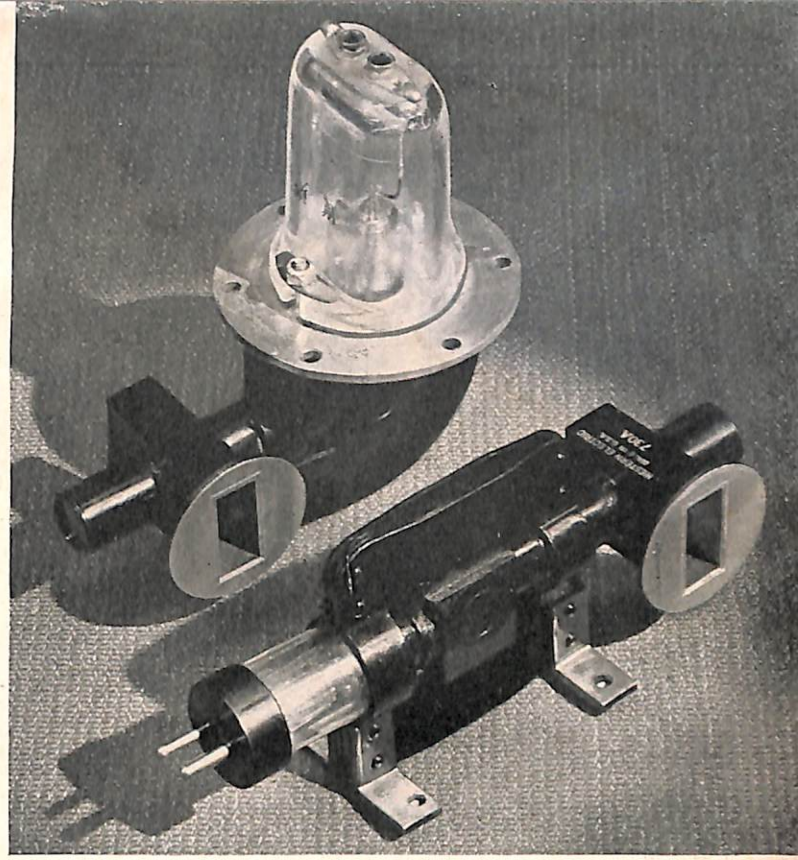
BUREAU OF SHIPS — NAVY DEPARTMENT

The Multi-Cavity Magnetron

Reprinted from Bell Telephone Laboratories RECORD.



Western Electric 725A and 730A three-centimeter magnetrons using external magnets. The 725A magnetron was used widely in Navy airborne radars and the 730A in Army radars during the bombing of Japan.

The superiority of United Nations radar was due in large measure to success in outdistancing the enemy in the utilization of wavelengths of less than 50 centimeters—popularly known as "microwaves." These very short waves provided the narrow beams, accuracy and target discrimination needed in precision fire-control and bombing. Early radars operated on waves more than a meter in length; progress toward shorter waves was severely limited by the absence of means for generating them at the high power level that is required.

Then came the multi-cavity magnetron which could generate powerful pulses of waves in the centimeter region. It made possible the reduction of operating wavelengths to 10 centimeters and by the end of the war to well under 3 centimeters. The development and perfection of this type of tube in Britain and the United States was therefore one of the outstanding engineering feats of World War II. In that work the Bell Telephone Laboratories played a leading part, particularly in developing the tube to operate at the higher frequencies that were desired and in adapting it to large-scale production.

The multi-cavity magnetron embodies within a single envelope a complete radio transmitter except for power supply and antenna. The inductance and capacitance which constitute the oscillating circuit are supplied by resonant cavities, as shown in figure 1. The inductance is centered mainly in the wall of the circular portion of the cavity and the capacitance in the walls of the slot. Each cavity, therefore, behaves like an inductance and a capacitance connected in parallel; the combination oscillates at a frequency which depends on the dimensions of the cavity and is the operating frequency of the tube. When the tube is in operation, electrons from the oxide-coated cathode circulate past the slots in such a way as to induce oscillating currents around the walls of the cavities. Through a coupling device in one of the resonators, the high-frequency energy is conducted into an output circuit and fed to an antenna through either a concentric cable or a wave guide.

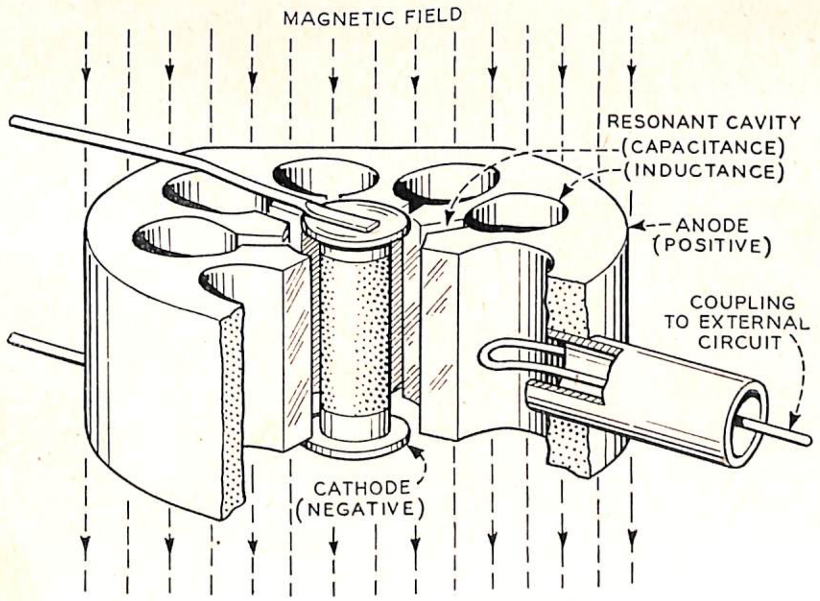
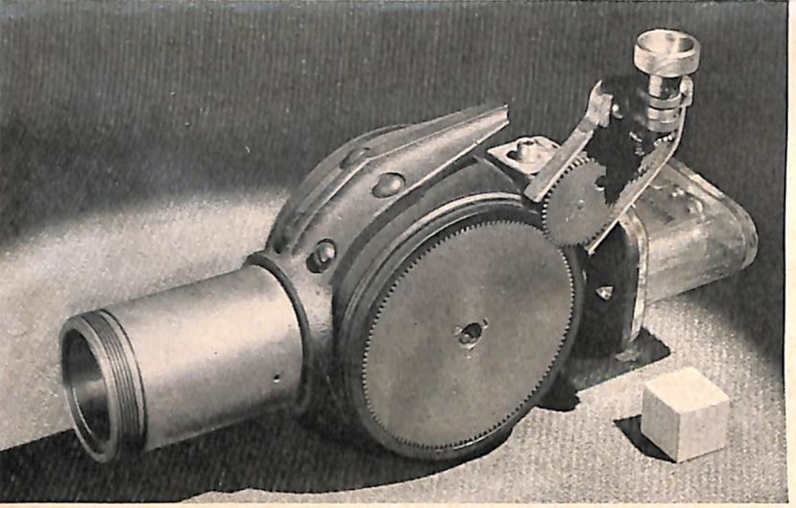
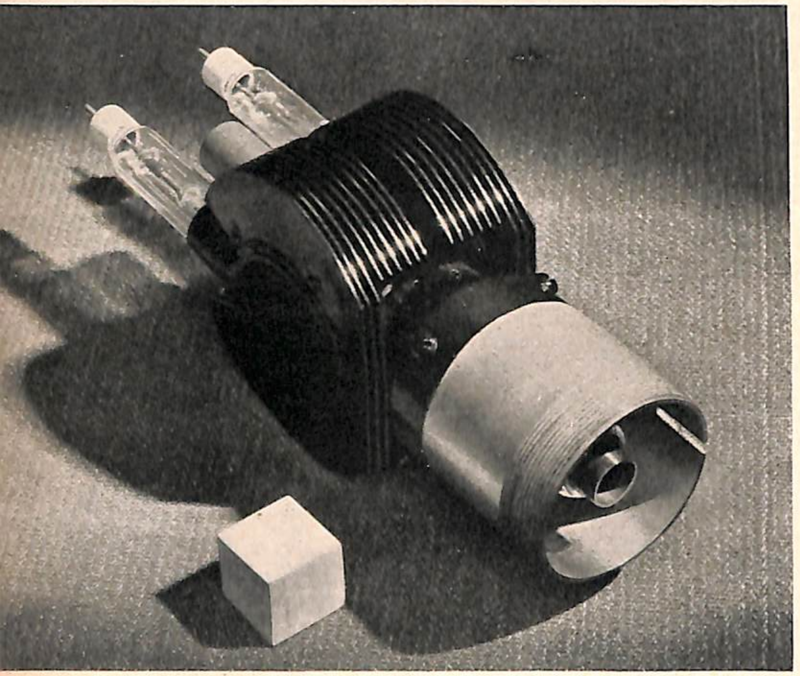


FIGURE 1—*The magnetron embodies within its envelope a complete transmitter except for power supply and antenna.*

The exact process whereby the electron stream interacts with the cavities to set them in oscillation is too complex for full description in this article, but the broad features may be seen

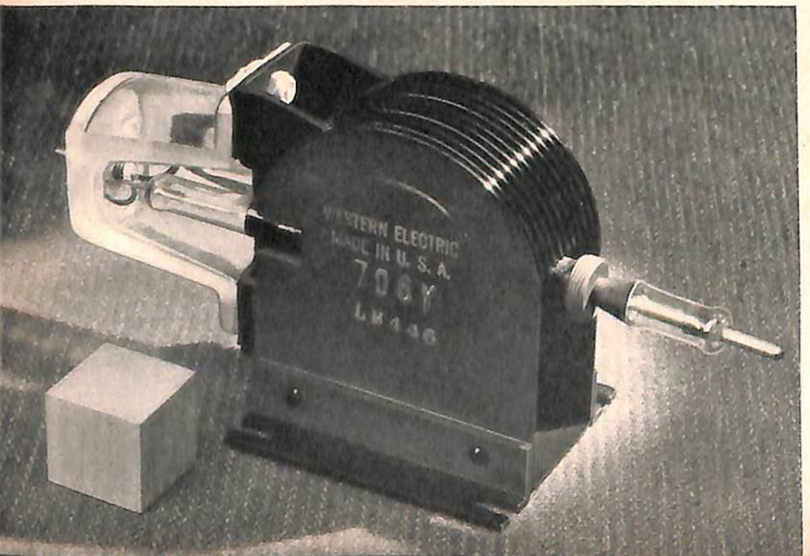


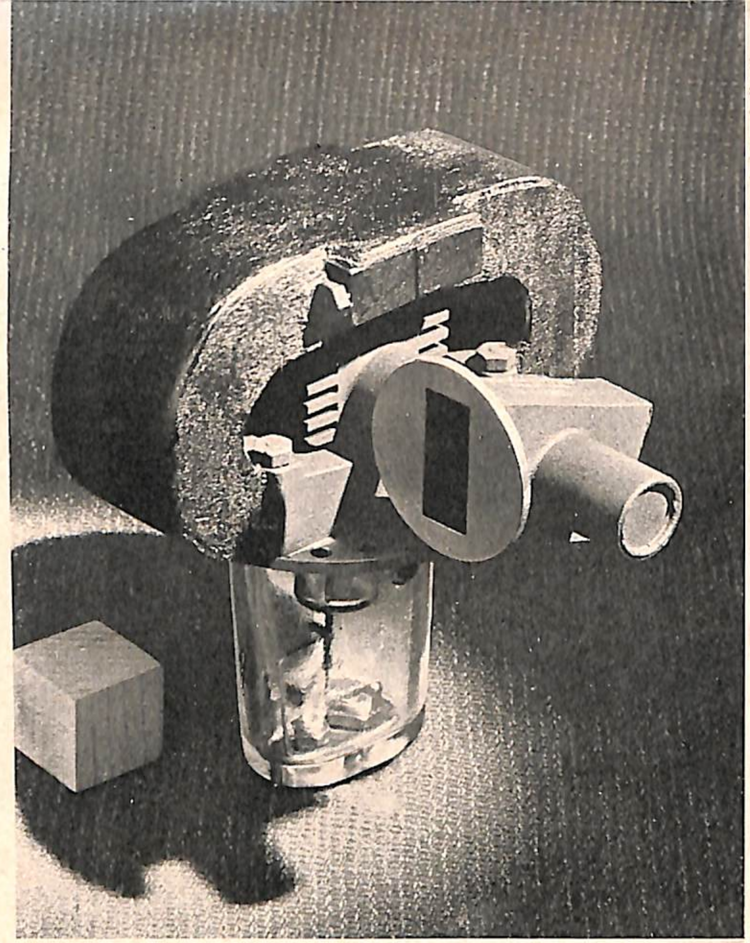
A thirty-centimeter high-power tunable magnetron (Western Electric 4J51).



A ten-centimeter high-power magnetron (Western Electric 720A) with concentric line output connection.

A ten-centimeter low-power magnetron (Western Electric 706Y).

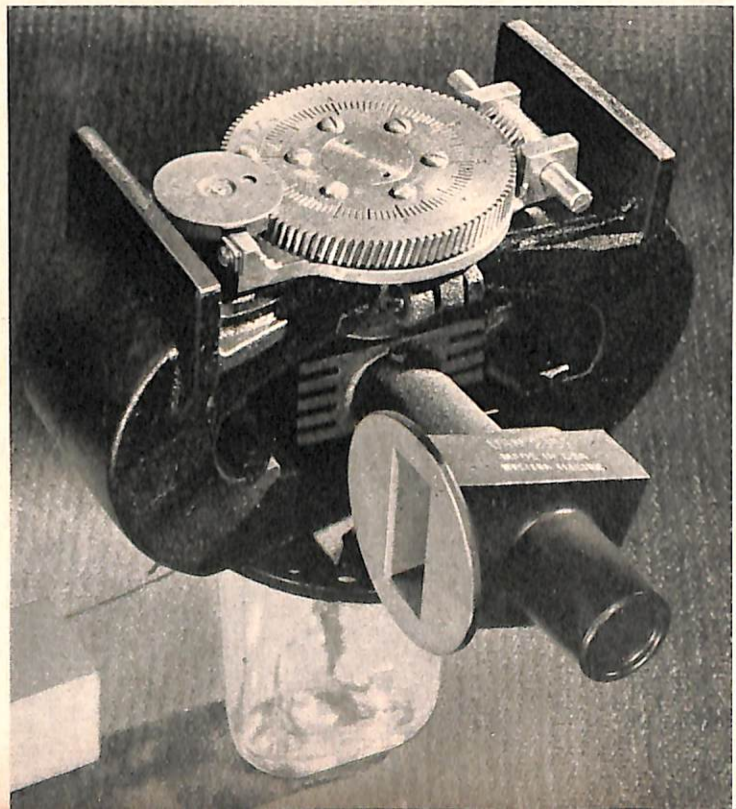




A three-centimeter wavelength magnetron (Western Electric 2J55) with integral magnet and wave-guide output connection.

(To indicate relative sizes, a one-inch cube block is shown with these magnetrons).

A three-centimeter magnetron (Western Electric 2J51) with integral magnet and tuning gear (shown at the top).



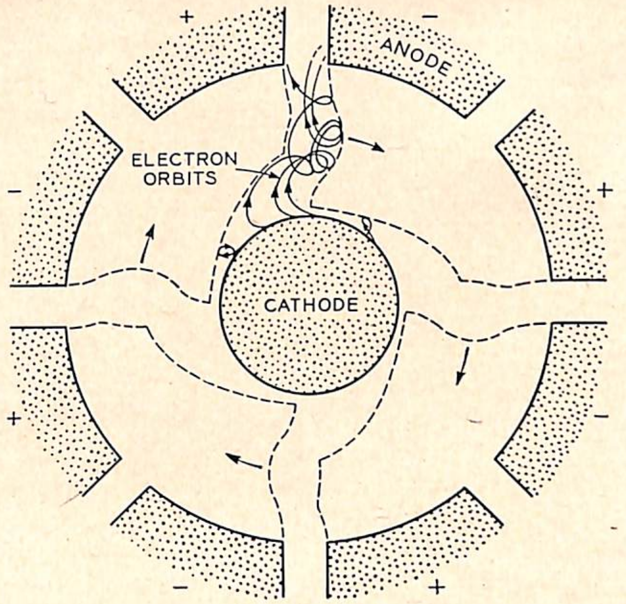


FIGURE 2—*Calculated configuration of space charge clouds in a magnetron. Curved lines represent electron paths as viewed by an observer travelling with the cloud. Based on the British Committee on Valve Development CVD Report, No. 41.*

from the following considerations. The electrons are pulled toward the anode by the positive potential; they are also swept sideways around the cathode by the magnetic field which acts downwards (see figure 1). Under the combined action of the electric and magnetic fields, the electrons are driven along curved paths across the front of the slots. Some of the electrons are swept back to bombard the cathode and this results in the emission of more electrons, a factor which contributes greatly to the very large currents which are drawn from the cathode. Other electrons strike the anode and so pass out into the plate circuit.

For each resonating cavity, one wall of the slot (plate of the resonating capacitance) is always electrically positive when the other is negative. Also the potential between the walls of a particular slot is at any instant the reverse of that for the adjacent slot. As the electrons approach a region of negative potential, they are repelled and slowed down while those behind approaching a positive potential are attracted and speeded up so as to close in on those in front. Thus the electrons do not proceed as a uniform stream, but collect into clouds so as to produce a pattern like the spokes of a revolving wheel in which the spokes represent maximum concentrations of electric charge as shown in figure 2. Each revolving cloud constitutes a surge of current which induces a corresponding surge of current around the walls of a cavity as it passes by. Phase relationships between the electron clouds and the resonating cavities are such that there is a net transfer of energy to the cavities.

In magnetrons used to produce radar pulses, the voltage is applied and the tube oscillates for only a few microseconds at a time, during which the cathode delivers many times the current level normal in other uses. Between pulses the tube remains idle for several hundred microseconds, during which heat is conducted away by the metal enclosure. It is therefore able to generate for short periods enormous amounts of power relative to its size. One high-power *L*-band magnetron delivered 6 microsecond pulses of 1000 kw with a current of 60 amperes and a plate potential of 30,000 volts.

Why a magnetron is a more favorable device for generating high-power energy at higher frequencies than the conventional vacuum tube appears from the following considerations. As is well known, the higher the frequency of operation of a circuit, the smaller the circuit elements become. This is also true of vacuum tubes. By the time that a conventional tube has been made small enough to operate in the centimeter wave region, it is too small to have any power-generating ability. Another consideration is that the time of travel of the electrons from the cathode to the plate needs to be reduced as the frequency of oscillation rises. Transit time can be decreased by employing smaller distances and higher voltages. But in a triode the combination of higher voltages and the smaller spacings becomes impractical at centimeter-wave frequencies.

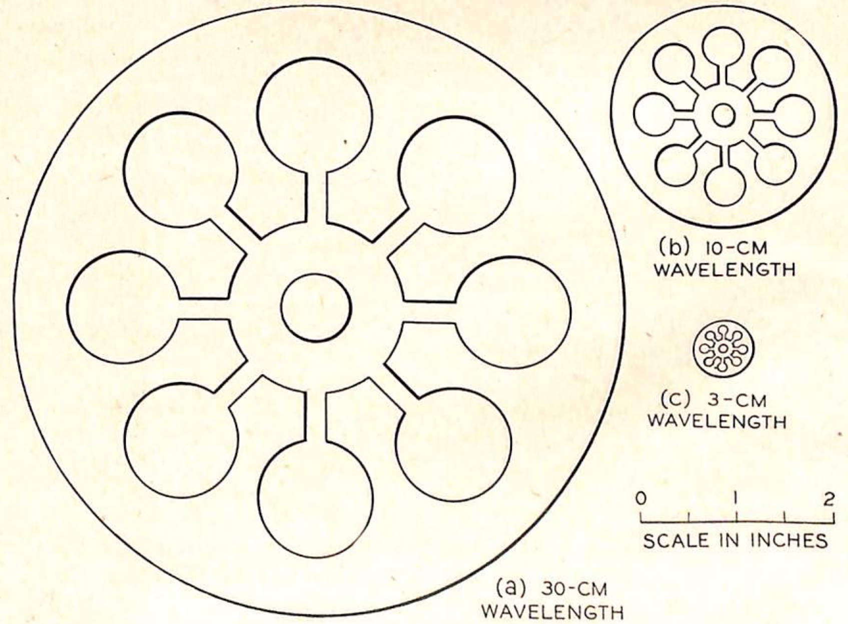


FIGURE 3—*Relative size of electrode systems in 30-, 10- and 3-centimeter magnetrons.*

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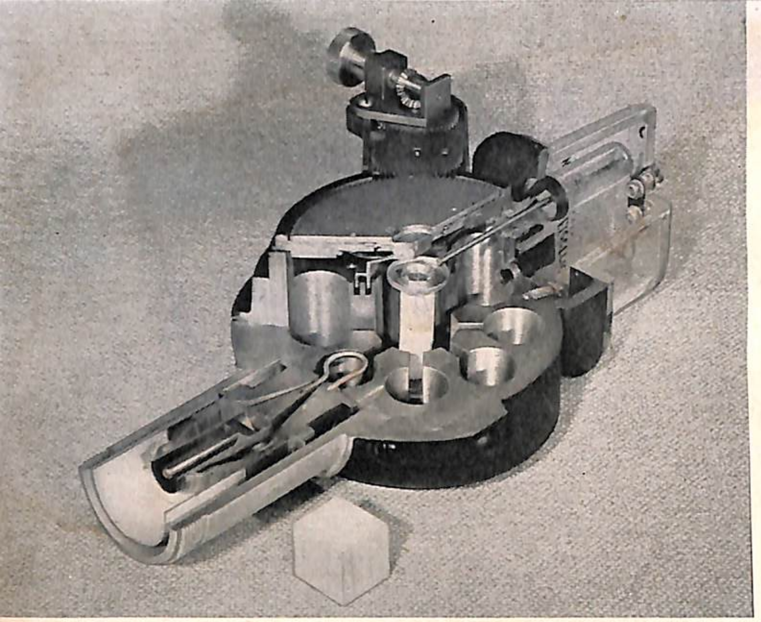


Cut-away model of the Western Electric 4J51 showing complicated internal structure.

In a multi-cavity magnetron the frequency-determining elements are provided by the electrodes inside the vacuum envelope. Moreover, the transit time of the electrons does not limit the operation of the magnetron in the same manner as in a triode. Using the magnetron principle, it is, therefore, physically possible to have structures of sizes which are able to oscillate in the centimeter wave region and also able to generate considerable power.

Even so, the magnetron is itself no exception to the rule of decreasing size with increasing frequency of operation, as may be seen from figure 3, which illustrates the relative sizes of the cathodes, anodes and cavities for wavelengths of 30 cm, 10 cm and 3 cm. Thus for the magnetron as for the triode there is an upper limit on the frequency of operation beyond which it is no longer a practical device. The magnetron, however, has the advantage of taking off from a higher frequency base than the triode. There is no inherent reason why a magnetron should not be used at low frequencies, except that the resonant cavities would be of unwieldy size. In practice triodes are advantageous down to approximately 45 cm and magnetrons for shorter wavelengths.

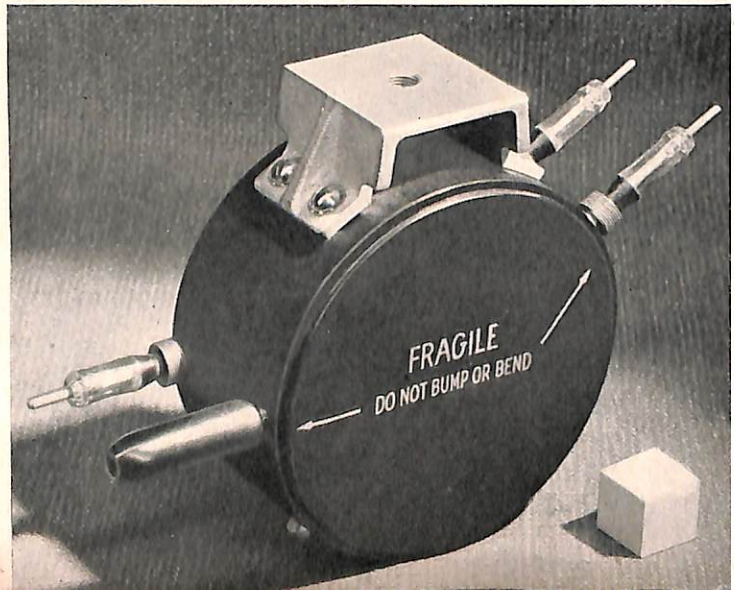
A limitation on multi-cavity magnetrons that should be noted is that they are essentially fixed-frequency devices and are not adaptable to tuning over as wide a band of frequencies as triodes. This comes about because the frequency-determining elements are inside the vacuum envelope and it is difficult to make extensive changes in the capacitances or inductances. However, limited tuning adjustment through vacuum seals has been incorporated in several magnetron designs.

The properties of magnetrons and resonant cavities were known long before the war. In Great Britain the multi-cavity magnetron underwent intensive development for radar. A model was brought to the United States in October, 1940, and was duplicated at Bell Telephone Laboratories in about one week, a tribute to the wide knowledge and experience in the electronic field of telephone scientists and the facilities of their laboratories. Almost immediately additional models were made available to the Laboratories' engineers, who were working on radar for the Army and Navy, and to the Radiation Laboratory of the National Defense Research Committee which was then getting under way.

A sizable development group of physicists, electrical engineers, mechanical engineers and chemists was organized to study the tube and exploit its possibilities. Throughout, the Laboratories worked in close cooperation with the Western Electric Company, whose long experience, not only in tube manufacture, but also in the mass production of precision parts, paid a rich dividend. There had to be means of brazing vacuum-tight joints in the metal enclosures without introducing damaging impurities. There had to be large-scale production methods for machining the electrodes to meet the critical tolerances on the frequency-controlling dimensions of the resonant cavities, especially with the tiny cavities required for the shorter wavelengths. (See figure 3.)

The first magnetron to be used in a centimeter-wave radar system by our Navy for fire-control was the Western Electric 700A, which was employed in the famous night engagement of the cruiser *Boise* and several other ships off Savo Island when six Japanese warships were sent to the bottom. In all, seventy-five Western Electric coded designs were developed, ranging from 45 cm to less than 3 cm, and from 10 kw to more than 1000 kw.

The first magnetron produced by the Western Electric Company. This is the 700A operating at 45 centimeters.



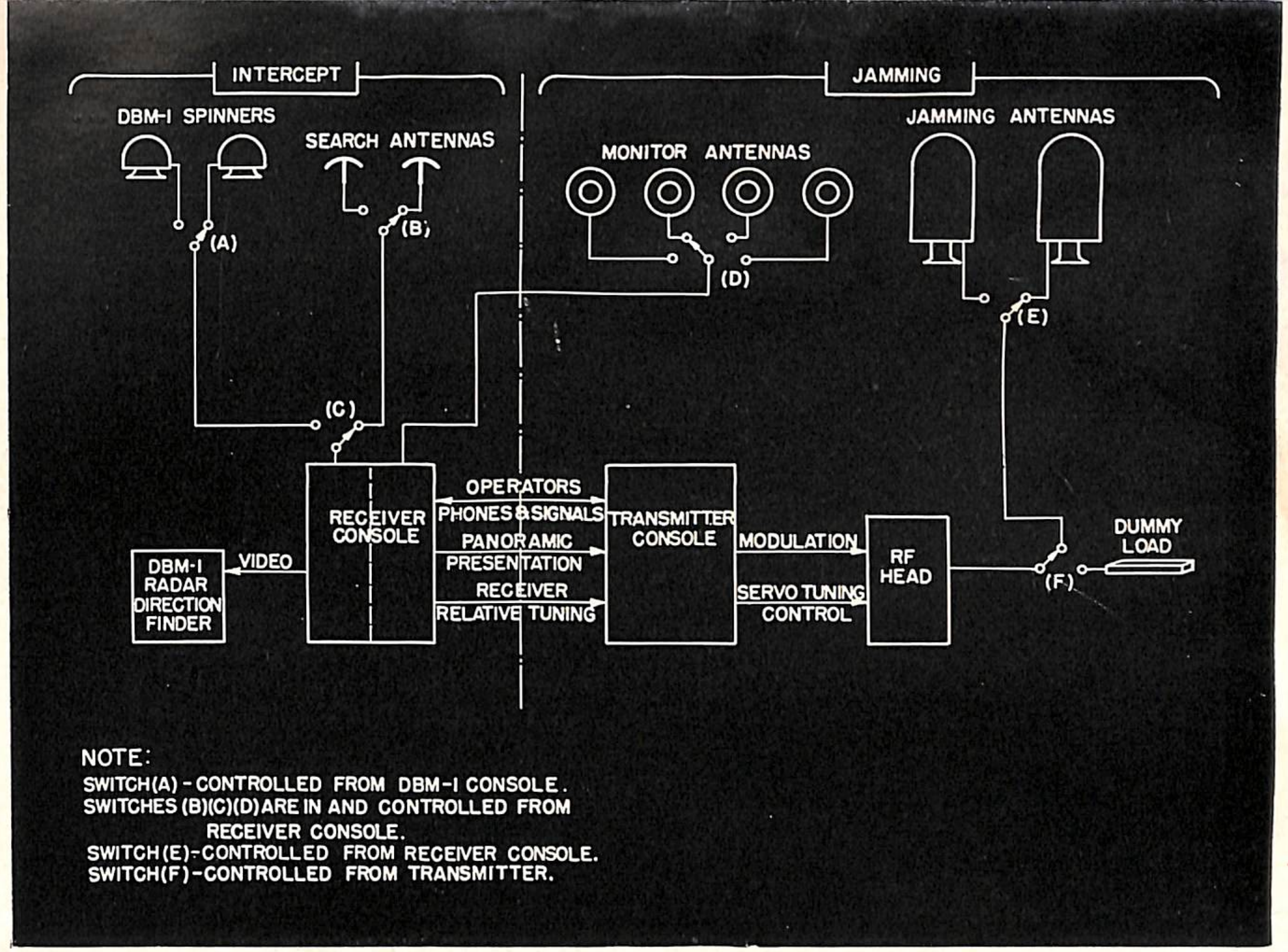


FIGURE 1—*Layout of equipment with major interconnections in a typical XMBT countermeasures installation.*

The RCM System of Tomorrow

■ Shipboard trials and operational tests have recently been completed on the latest development in RCM intercept and jamming systems, the XMBT *(Elephant)*. This equipment is the first attempt at a high-powered noise-jamming and completely coordinated intercept system in which all components are integrated and controlled as a system, affording the advantages of most effective and efficient operation.

The XMBT was designed as the result of a long recognized need in the Fleet for better RCM equipment coordination. The present Navy shipborne RCM intercept and jamming system is a heterogeneous assembly of equipment which includes receivers, jammers, pulse analyzers, panoramic adaptors, wave traps, and direction-finding gear. Most of the equipments were designed for a specific wartime need, often on a crash basis, and many of them for use in aircraft. The resultant combination of these various units into an operating system must perform many functions, but accomplishes none to the best advantage. This has also resulted in many installation and interconnection problems. Operators have to be skilled in the use of a large variety of equipment, and even with the Navy's standard arrangement of RCM rooms which came out near the end of the war, the system at best is unwieldy and leaves much to be desired in the way of efficiency.

Continuous monitoring of the victim radar cannot be accomplished with the present system equipment. Look-through requires that the jammer be shifted off frequency or turned off momentarily. The XMBT system is designed to provide continuous look-through, with the jammer operating continually and on frequency.

The rated power output of the only *S*-band radar jammer in service use, the TDY-1A, is 50 to 75 watts as compared with the 1000-watt output of the XMBT. This is an increase in jamming power of about 13 db.

In the XMBT all circuits necessary to intercept, pulse-analyze and jam victim radars are incorporated in two large consoles (Search and Transmitter). A smaller Oscillator Unit containing the continuously-tunable magnetron may be located either in the RCM room or at a remote point nearer the antenna. The major units of the system are indicated in the block diagram. The DBM-1 radar direction finder is used as associated equipment.

The system is designed to cover a broad frequency range, ultimately utilizing a series of r-f heads in both the receiver and transmitter. The time required to change transmitter frequency and jam a radar signal or another frequency within the range of any r-f head is less than thirty seconds, and is accomplished without the need of an operator in attendance at the Oscillator Unit. The magnetron is tuned by remote control with frequency indication at the Transmitter Console. In the laboratory prototype used for the shipboard tests, only the 2000-to-4000 Mc receiver tuners and 2460-to-3610 Mc transmitter r-f unit were available for complete system tests. A laboratory model of a 90-250 Mc Oscillator Unit for the transmitter had been built, and tests of this unit were made using an RDO Receiver and RDP Panoramic Presentation Unit in place of the XMBT Search Console.

The Search Console contains two identical receivers which function interchangeably as "search" or "monitor". Although this may seem to be a duplication of equipment at the expense of space and weight, it is considered to offer several operational advantages. In previous systems it has not been possible to carry on general search functions while the receiver was being engaged in monitoring a signal being jammed. With only one receiver it would generally be necessary to employ a division between ships of intercept and jamming functions. The time and training required to reach an effective degree of skill and coordination of operations, in case such a division were made, would, in view of past experience, more than offset any advantage gained in the space and weight saved. In addition some standby facility is gained in that, in case of prolonged loss of service of either receiver due to unforeseen trouble, the other receiver can immediately be switched into service. The switching is accomplished by a simple two-position front-panel control which designates either receiver as the "search" function, with antennas and all necessary circuits being automatically switched to the other receiver as the "monitor". The switching feature adds greatly to the ease and accuracy of remote indication of receiver frequency at the Transmitter Console, since it is not necessary to manually set in the frequency of the "monitor" receiver.

There has long been a need in RCM work for a system that allows rapid, positive identification of the characteristics of a radar signal. Previous equipments have failed in many respects. One of the most troublesome problems has been the lack of positive determination of carrier frequency because image and harmonic responses in previous receivers have allowed the operator to get an indication from a single radar at several settings of the tuning dial. The first stage of the XMBT receiver is so selective that no harmonic responses occur and only very strong signals give trouble with image responses. With an indication found at only one setting of the tuning dial the determination of carrier frequency is greatly simplified. The identification of signals is still a problem when a large number of radars are operating near the same frequency. In this respect the XMBT is considered good and an improvement over previous receivers. Differentiating between radar signals in the *S*-band becomes difficult only when they are within a half-megacycle of each other.

The determination of pulse width and pulse repetition rate is greatly simplified in the XMBT by use of direct-reading meters. This method is a great simplification of previous methods and helps to prevent mistakes caused by confusion and fatigue. It is likely that future models will incorporate an auxilliary CRO in addition to the meters to permit more detailed pulse analysis when conditions permit.

The search Console also includes a panoramascope for each receiver to give a visual plot of signals versus frequency, audio output jacks, transmitting antenna train controls, search-sequence controls, and receiver power supplies. The search-sequence control greatly simplifies the search procedure in that by means of a single front-panel switch all circuits are automatically switched to permit the proper 1-2-3 order of events necessary to conduct the search operation.

The XMBT system normally requires three operators, working in conjunction with CIC, with sound-powered phone circuits between operators located at remote points. The search operator is primarily responsible for the operation of the system. Stationed at the Search Console, he has the responsibility of searching for, identifying, recording, and reporting to CIC all information on intercepted radar signals, including bearing data found by the DBM operator. The search operator must also control, upon orders from CIC, the sequences necessary to jam an intercepted signal, including training of the transmitter antenna and monitoring duties in conjunction with the transmitter operator. The transmitter operator is responsible for the adjustment of all controls at the transmitter console necessary to maintain the transmitter in optimum adjustment, to set the jammer on frequency, and to regulate the character of the jamming spectrum. The transmitter operator must also make adjustments for optimum look-through to assist in the monitoring function. The DBM operator is stationed at the DBM indicator, normally adjacent to the search console, and his duties are to obtain D/F information, either from operation of the DBM or via sound-powered phone circuits with search radar or CIC stations. In an emergency the functions of the search and DBM operators may be combined.

During normal search operation the search operator observes and records data on the various radar signals intercepted by the selected search antenna. The search receiver is either manually or automatically tuned over the frequency range covered by the receiver r-f head presently inserted in the search console. Information normally sufficient to identify all signals is obtained. When the decision is made to jam a particular radar signal, the search receiver is carefully tuned to its frequency and then switched to monitor function, thereby automatically accomplishing three operations: 1—the receiver is connected to a selected monitor antenna; 2—a dial indication of the radar frequency is transmitted and indicated at the transmitter console; and 3—the *panoramascope* presentation for the monitor receiver is repeated on the extension panoramascope at the transmitter console. The search operator then gives the "prepare-to-jam" signal.

The transmitter operator will then make preliminary adjustments, selecting either clipped or unclipped noise for modulating the magnetron, r-f energy of which is always initially fed into the dummy load. The magnetron is remotely tuned from the transmitter console and its frequency, relative to that of the receiver, is adjusted roughly by matching the dial indications of transmitter and receiver frequency. When the two dials are approximately matched the jamming spectrum appears on the panoramascope where more accurate magnetron tuning places it over the victim. By means of an attenuator and line stretcher the amplitude and phase of the jamming spectrum seen on the panoramascope is adjusted so that the radar signal may be seen on top of the jamming spectrum, thus making continuous monitoring and look-through possible.

When jamming is commenced the transmitter operator switches from dummy load to the transmitting antenna system. The switchover from port to starboard antenna as the bearing changes is automatic. The transmitter operator now has remote control over the monitor receiver tuning in order to keep the radar signal centered in the pass band of the receiver. The receiver which is now on search function is switched to the appropriate DMB-1 spinner antenna and its video output fed to the DBM-1 indicator.

D/F information for purposes of transmitter antenna train is obtained from the DBM-1 or from CIC, whichever has the better data. Bearing data is relayed by the DBM operator to the search operator, who now has the additional duty of maintaining the transmitting antenna on the bearing of the victim radar. Aside from this latter duty the search operator is free to continue searching for other radar signals with the search receiver.

The transmitting antennas are circularly polarized, with a horizontal beam width of 10 to 12 degrees and vertical beam width of 27 to 30 degrees. Antenna gain is about 17 db. The two antennas (port and starboard) were deck-mounted approximately amidships, and approximately 18 to 20 feet above the water line. An outboard mounting was used in certain phases of the test but is not intended as a feature for future installations.

Other antennas normally used in the XMBT system include the port, starboard, bow, and stern monitor antennas, and the DBM high-frequency spinner. A system whereby the number of monitor antennas may be reduced is presently under consideration.

In summarizing the results of the tests with regard to the capabilities and limitations of the XMBT system the following excerpts are taken from the Report of the Operational Development Force:

"The XMBT equipment can effectively intercept, identify and jam the *S*-band surface and air-search radars, shipborne, airborne, and shore-based, tested thus far. . . "

"The XMBT is capable of very effective operation against *S*-band air- and surface-search radars and somewhat less effective operation against *S*-band fire-control radars . . . " (In these tests the equipment was used against SG, SP, SX, Mk-8, Mk-28, SC-5, AN/APS-2E, AN/APS-2F, and SCR-584 types of radars.)

"It was found that radars could be intercepted and identified, and the jammer operator could be prepared to jam effectively, while the jamming ship is still beyond detection range of the victim radar. Identification of a radar signal is a short and fairly simple process with the XMBT, and good operators can be prepared to jam a signal in one minute, average time."

"Maximum intercept and D/F range of shipboard radars is satisfactory for the purpose of jamming with this equipment. SP radar is intercepted consistently at greater range than other search radars. Radar intercept and D/F has been consistently good, and it is considered that the performance of monitor antennas is satisfactory".

"It is felt that the XMBT system with its facility for rapid signal identification and analysis, its high power output, continuous monitoring during jamming, and compact packaging represents a great advance in radar countermeasures."

"The flexibility and compactness of this system make it suitable for installation in large combat and auxilliary-type ships and in large destroyers. Its ease of operation and performance make it very desirable that XMBT replace TDY jammers and associated intercept and analyzing equipment aboard Navy ships."

"The system is flexible, and should be adaptable to various installations. It is readily accessible to maintenance and servicing; all inside work can be done from the front of the consoles. Weight of the equipment does not seem excessive in comparison with other jamming systems."

"Analysis of several radar signals close together in frequency is possible with this equipment. A radar signal can be intercepted and identified with no difficulty, even with other signals present within one megacycle in frequency. However, it was found that signals from radars on the jamming ship can hide other radar signals, on the same frequency, from intercept equipment."

"Interference between XMBT and shipboard radar and radio equipment was not noticed during these exercises. . . . The Task Force Commander concludes that such interference is not a problem. During a radar identification phase, the Mark 34 radar was jammed twice. At the time the jammer was being tuned through a band of frequencies about one-third the value of the frequency of the Mark 34. Further test might disclose whether this interference was actually caused by a third harmonic of the jamming signal, as was suspected at the time."

"Instances were noted in which radar signals 10-25 megacycles from jammed frequency were also jammed. In another instance, SP radar at 2824 Mc was affected during jamming of SX radar at 2860 Mc, but the SP could still track the jamming ship. In other cases radar signals only 10 Mc from frequency of jamming were not affected. The Task Force Commander concludes that own jamming should be observed on search scope at frequent intervals, since inaccurate adjustment of transmitter spectrum will result in spreading the jamming over as much as 25 to 40 megacycles. The clipper used with spectrum adjustment will aid in eliminating interference with radar signals close to frequency being jammed." (The above illustrates design problems and compromises with provision for spectrum adjustment on the one hand to be narrow enough not to cause interference, but suitable for jamming wide-pulse search radars, and on the other hand to permit broadening the spectrum sufficiently to allow effective jamming of narrow-pulse fire control radars, but still not cause off-channel interference.)

TABLE 1—*Data obtained on operation of the XMBT in intercepting various types of airborne and surface radars.*

Exercise Phase No.:	**1A**	**5A**	**28**	**28**	**28**	**18**	**19**	**18A**	**12**	**12A**
Target Vessel or Aircraft:	Blimp	TBM	Shore-based at Beavertail Pt. R.I.			USS Goodrich (DD831)		USS Tucker (DD875)	USS Augusta (CA31)	
Radar Type:	APS-2	APS-2	SX	SP	SG	SP	SG	SG-MTI	MK8	MK8
Frequency in Mc:	3300	3300	2860	2824	3036	2810	3100	3060	3045	3080
Peak power in kw:	50	50	1000	700	50	700	50	50	25	25
Antenna gain in db:			37.6	29.5	28	29.5	28	28	28	28
Beam power, megawatts	19	19	5760	624	31.6	624	31.6	31.6	15.8	15.8
Antenna height, ft.:	1000	10,000	107	184	147	57	85	85	105	105
UHF line-of-sight distance, mi:[4]	49.4	133	23.4	27.2	25.5	19.9	21.9	21.9	....	23.2
Maximum radar interception of Asheville in mi:	....	90	....	23.5	17.0	....	....	....	10.8	15.8
Maximum X-MBT intercept range, mi. on AS=44/APR antenna:	49.1	95[1 2 3]	29.1	34.7	32.9	25.0	20.0	22.0	21.0	25.0

NOTES: [1] Maximum intercept on AS-45/APR antenna—52.0 miles.
[2] Maximum intercept on DBM-1 antenna 40.0 miles.
[3] On all other intercept ranges given the DBM-1 maximum range is at least equal to that of the AS-44.
[4] UHF line of sight distances are computed using the theoretical 4/3 r for the earth's radius.

TABLE 2—*Jamming data obtained during trials of the XMBT. Note relatively weak results against fire control due to their wide-bandwidth receivers.*

Exercise Phase No.:	**12**	**12A**	**28**	**18**	**19**	**18A**
Target Vessel:	USS Augusta (CA31)		Shore based	USS Goodrich		USS Tucker
Radar Type:	MK 8	MK 8	SX	SP	SG	SG-MTI
First Glimpses of Jamming Ship on Radar, Yd.:	7270	10400	none			5260
Minimum Effective Jamming Range, Yd.:	7000	10000	6000	7000	4700	none
Look-through Charac:						
Monitor Antenna	Good at ranges less than 21,500 yd.	Good below 20,000 yd.	Good at all times	Good at all times	Good at all ranges	intermittently
DBM-1 Antenna				Good less than 30,000		
Antenna Mounting:	outboard	topside	outboard	inboard	outboard	outboard
Power Output of Jammer, watts:	600	800	875			
Sea conditions:	Heavy	Calm	Very calm	Very heavy	Moderately calm	Moderately calm

"The task of training personnel to operate the XMBT is relatively simple. The controls are logically located and clearly labeled. A week's training should be sufficient to allow a technician already familiar with other RCM equipment to become thoroughly familiar with this equipment. The XMBT is such a compact setup that training men in its operation is much easier than in the (so-called) standardized set-up."

"It was found impossible to screen another ship, making a torpedo attack, from fire control radar aboard the victim (target) ship. During one test, Mark-8 radar detected the attacking ship at first range of more than 16,000 yards, and could track attacking ship at a range greater than maximum low-speed torpedo range. Fire-control radars Mark 8 and Mark 28 could not be jammed effectively within 10,000 yards when jamming ship was beam-on to victim radar. Both radars could obtain ranges by detuning the local oscillators. From these tests it is concluded that XMBT spectrum must be broadened to reduce minimum jamming range against *S*-band fire-control radars."

"It is, however, possible to protect a ship from radar torpedo attack by aircraft. In several runs passing directly over the ship, airborne radar was jammed completely, and radar could give no information of ship's position. Aircraft can direct their course in the early stages of an attack by taking the bearing of the jammed sector, but upon close approach the scope seems to be blocked uniformly in 360 degrees, not affording an accurate bearing for an attack."

It is pointed out that these were preliminary trials of the laboratory prototype of the equipment and that much time will elapse before other trials, design changes, and quantity production will have been attained. The information presented herein is not to be construed as indicating an early delivery date for these equipments, but only to familiarize the service with the capabilities and limitations of this equipment, delivery date of which is indefinite.

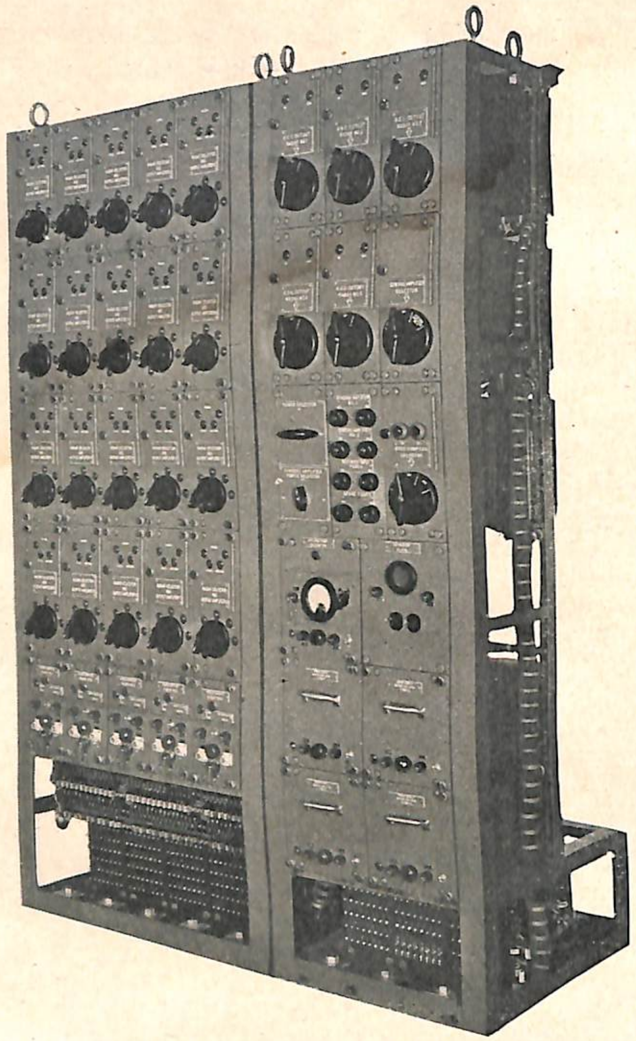


Figure 1—*Model CM23AFL Radar Distribution Switchboard, front view.*

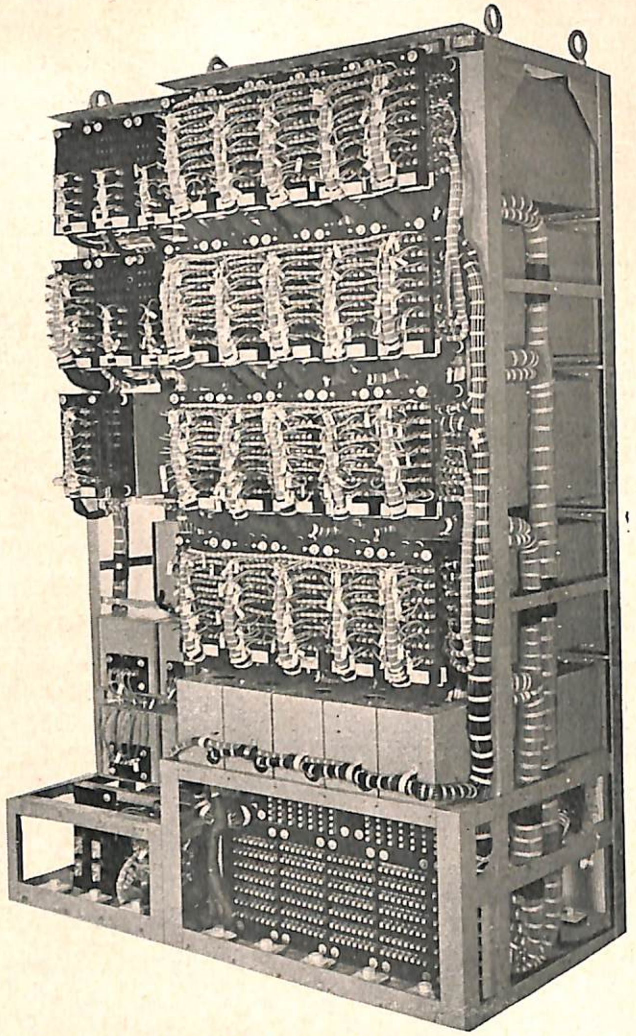


Figure 2—*Model CM23AFL Radar Distribution Switchboard, rear view, exposing maze of wires and cabling in the system.*

The Radar Distribution Switchboard

By Lt. Comdr. R. D. Chipp, USNR, *BuShips*

■ Early in the war it became evident that the PPI *(Plan Position Indicator)*, as a means of displaying radar information, was superior in most respects to other types of presentation. The first PPI's were built as a part of the radar equipment. A logical development was to design remote PPI's that could be placed about the ship in various strategic locations to repeat the information appearing on the so-called *master* PPI. The video and trigger output signal levels from all radar sets were standardized, and remote PPI's, now called radar *repeaters,* were designed so that they could be switched from one radar to another at the option of the user. Initially, the quantity of repeaters installed was sufficiently small so that each repeater could receive its video, trigger, and synchro signals on a separate circuit. However, as Fleet requests for repeaters increased, the allowance list was modified and it became necessary to put as many as four repeaters on the same string. (See p. 5, June 1946 Electron.) This type of repeater installation is not altogether satisfactory for three principal reasons: 1—lack of sufficient isolation results in poor battle-damage protection for the balance of the system; 2—stray capacity bridged across each line tends to deteriorate the signals received at the repeaters; and 3—cables required to feed information on separate lines from each radar to each repeater result in excessive space and weight requirements.

With the above facts in mind, the Bureau began planning for a type of radar distribution switchboard which ultimately would be located within the armored box of all CL's and larger. There are two models of the RDS *(Radar Distribution Switchboard).* The earlier one is model 23AFL, and is designed to handle all the circuits necessary for receiving information from one to five radars and transmitting this information to as many as twenty repeaters. The later model, No. 23AGU, was constructed with emphasis on front-servicing and easy replacement of electronic sub-assemblies. Electrically it is similar to the first model, but will handle six radars and twenty repeaters. A more complete description of the later model will appear in a future issue of the Electron. Front and back views of model 23AFL, which will be discussed in the following paragraphs, are shown in figures 1 and 2. Each radar and each repeater has its own separate connecting lines to the RDS, so that it is possible to effect immediate and complete isolation from the system in case of battle damage.

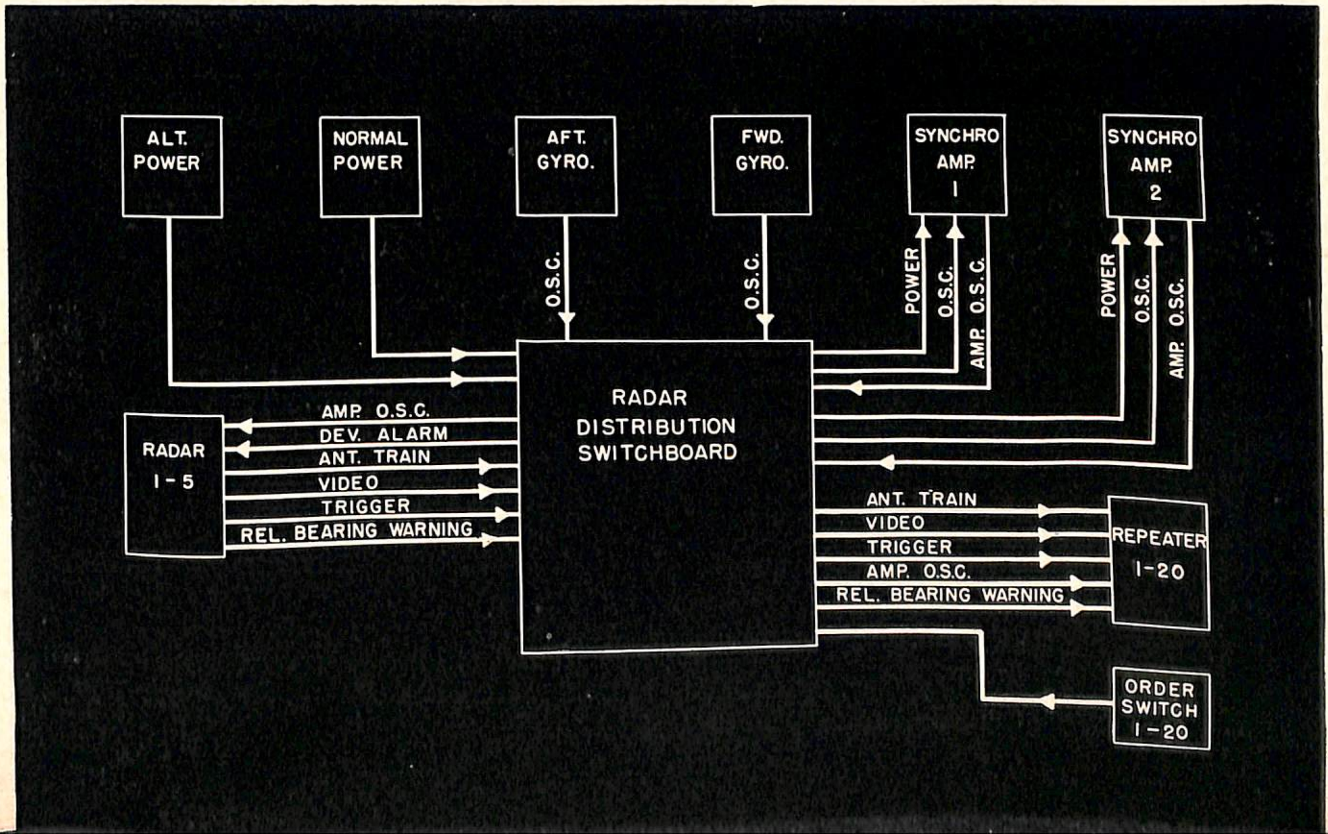
In order to explain the functioning of the RDS, it may be well to review the signals required to operate a radar repeater:

SIGNAL	FUNCTION
video	target echo from radar receiver output.
trigger	positive pulse from radar transmitter which initiates the sweep circuits in the PPI.
antenna train	1-speed or 1- and 36-speed synchro information for repeating position of radar antenna.
own-ship's-course (OSC)	1-speed or 1- and 36-speed to permit relative bearing indication at repeaters, when desired.
relative-bearing warning-light circuit.	6- to 8-v signal circuit to indicate at the repeater that radar antenna train information is in relative bearing.

In addition to receiving from each radar and feeding to each repeater the circuits tabulated above, the RDS is equipped to control and switch gyro compass, synchro amplifier, and deviation alarm circuits between the radars and the RDS. Figure 3 is a simple block diagram of an RDS installation. Referring to figure 3, consider for the moment only the circuits external to the RDS in order to analyze the function of the switchboard.

There are two sources of incoming power, one for normal use and the other for emergency use. Likewise there are two sources of gyro signal, the forward gyro compass and the after gyro compass. In the same manner, there is provision for two synchro amplifiers, external to the RDS, which amplify the gyro signal and feed OSC (*own-ship's-course*) information to all radars and to those repeaters which require OSC information (VF and VG). There is also a deviation alarm circuit which becomes energized if there is a power failure in the OSC primary circuit.

Figure 3—*Simple block diagram of a Radar Distribution Switchboard showing various inputs and outputs required to make the system function correctly.*



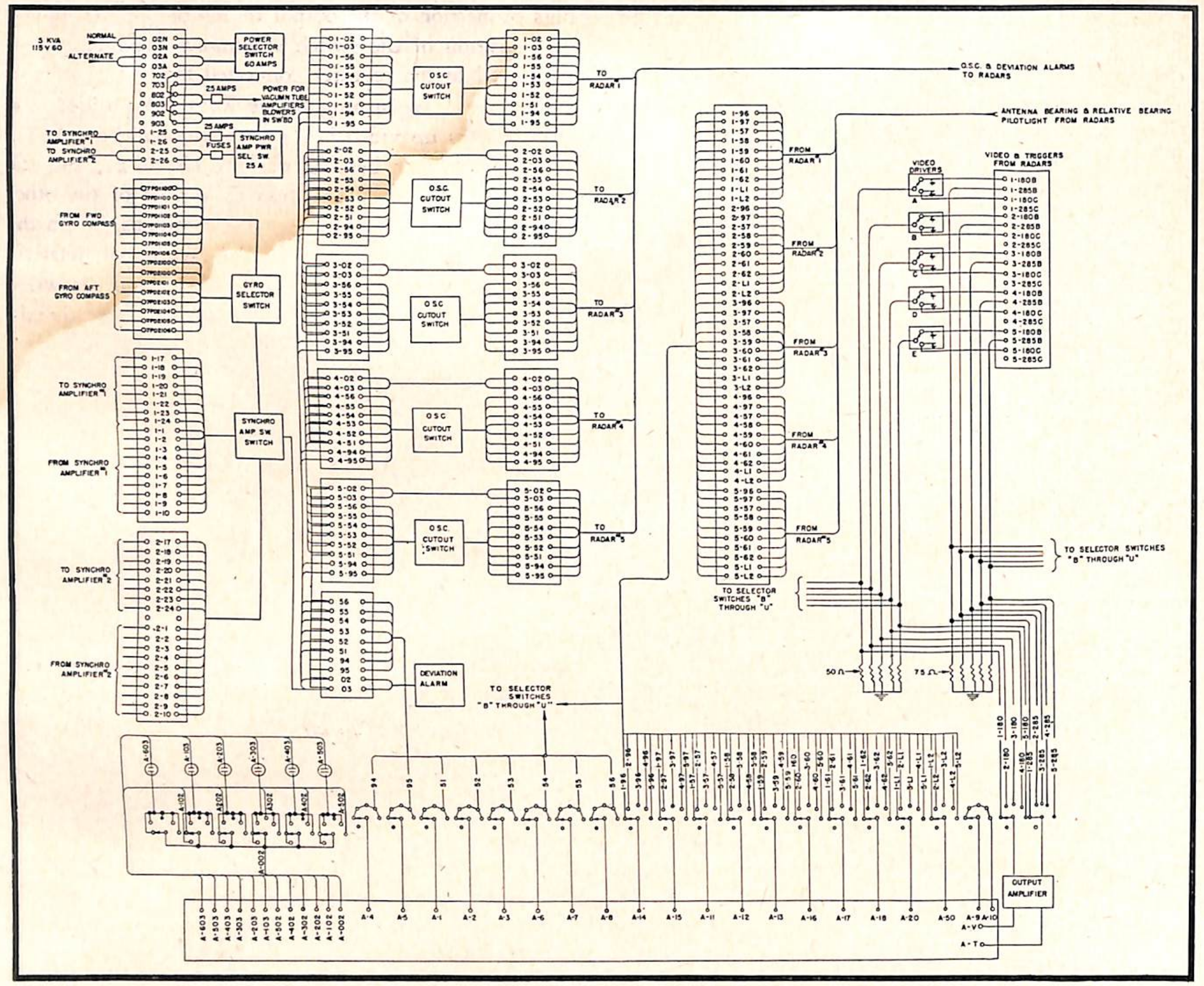


FIGURE 4—*Routing and switching of various circuits through the Radar Distribution Switchboard.*

Each radar receives OSC and deviation alarm signals from the radar distribution switchboard. Each radar delivers video, trigger, antenna train, and relative-bearing-light voltages to the RDS. Normally radar antenna train is in true bearing, but if the OSC should fail, as indicated by the deviation alarm, the radar system is swung over to relative-bearing operation. Under these conditions antenna train is in relative bearing, and the relative-bearing warning circuit is energized.

Each radar repeater receives from the RDS regular and emergency video, regular and emergency trigger, antenna train, relative bearing warning-light circuits, and OSC if required. In addition, for each of the 20 repeaters there is an order circuit which is used to indicate the radar system desired at any given repeater. With repeaters Models VC through VH, this order circuit terminates in an external order switch, located near the repeater. With repeaters VJ, VK, or later models, the order switch is built into the repeater.

Figure 4 is a simplified diagram showing how the various circuits described above are routed and switched within the RDS. Following the same order as in the preceding paragraph, it will be noted that the power selector switch selects either normal or emergency power and feeds it to the rectifier supplies and to the synchro amplifier power selector switch.

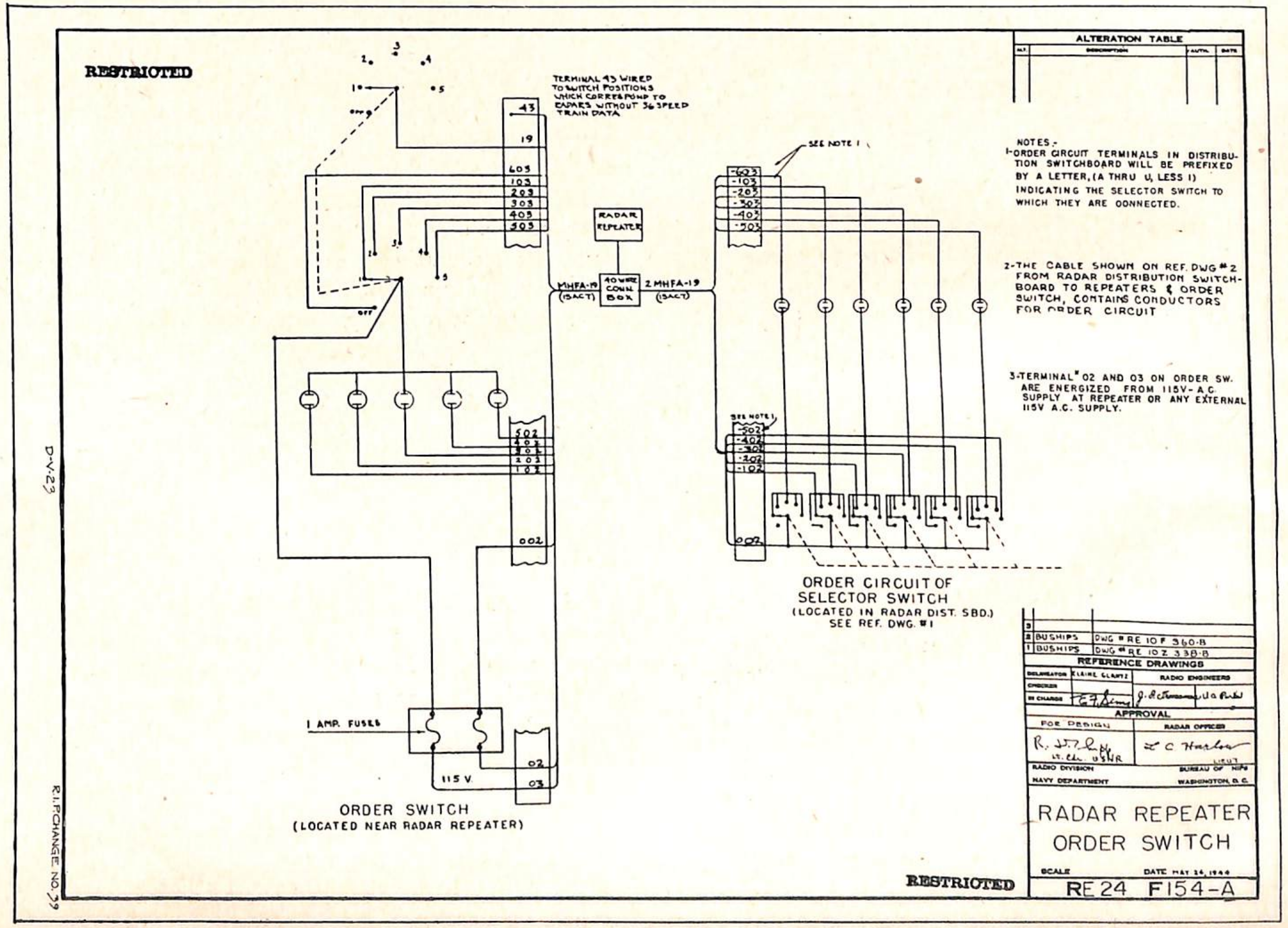
The rectifier power supplies are conventional units which provide B+ and filament voltage to the output amplifiers. The internal RDS wiring is arranged so that each power supply feeds five of the 20 output amplifiers. The gyro selector switch selects either the forward or after gyro compass and feeds the selected information to the synchro amplifier selector switch. The synchro amplifier power selector and the synchro amplifier selector switch are always operated together. Their position determines which of the two synchro amplifiers will be energized and will receive the gyro information. The synchro amplifier selector switch also feeds the output of the selected synchro amplifier to the OSC bus within the RDS.

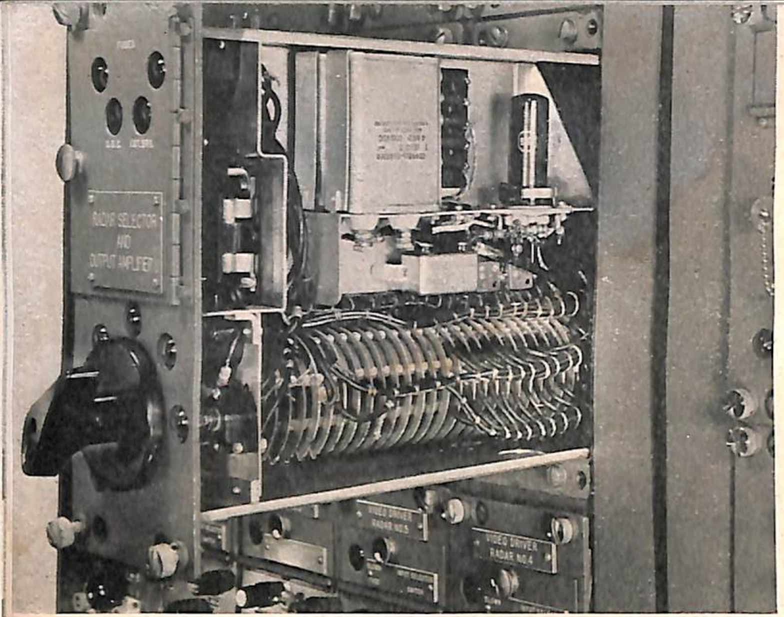
Each radar receives its own-ship's-course information from the OSC bus, through an OSC cutout switch equipped with overload indication. This permits isolation of any defective or damaged radar from the OSC bus. Each radar receives the deviation alarm information by means of a relay in the synchro amplifier which closes the deviation alarm circuit. There is also a deviation alarm light and buzzer in the RDS to warn the switchboard operator of failure in the synchro amplifier.

Now consider the circuits feeding the RDS from the radars. The received video signals from a radar are amplified in a video driver associated with that radar, the output of which may be called the *video bus* for that particular radar. This video bus is wired to each of twenty radar selector switches. Likewise, the trigger signals received from this radar are fed without amplification to what may be called a *trigger bus,* and thence to the twenty radar selector switches. Similarly, the antenna train signal and the relative-bearing warning circuit from this radar, as well as the OSC bus, are wired to each of the twenty switches. Each radar selector switch is a multiple-deck 3JR switch. The switch is simply a group of tap switches operated by a common shaft, and permits connection of the output to any one of the inputs. The position of the switch determines the information to be fed to the repeater connected to its output taps. For example, by turning to the Radar #1 position, the switch picks up video bus #1, trigger bus #1, antenna train and relative bearing warning circuit #1, and the OSC bus. Similar information from each of the other radars appears on the other switch positions. From the output of the switch the antenna train signal, relative-bearing warning circuit and the OSC circuit are wired directly to the repeaters. The video and trigger signals, however, are fed through two cathode followers wired in an assembly known as the *output amplifier.* These output amplifiers serve the purpose of stabilizing the video and trigger voltage levels, isolating each repeater from the switchboard, and permitting individual low-impedance coaxial feed lines to be run to each repeater.

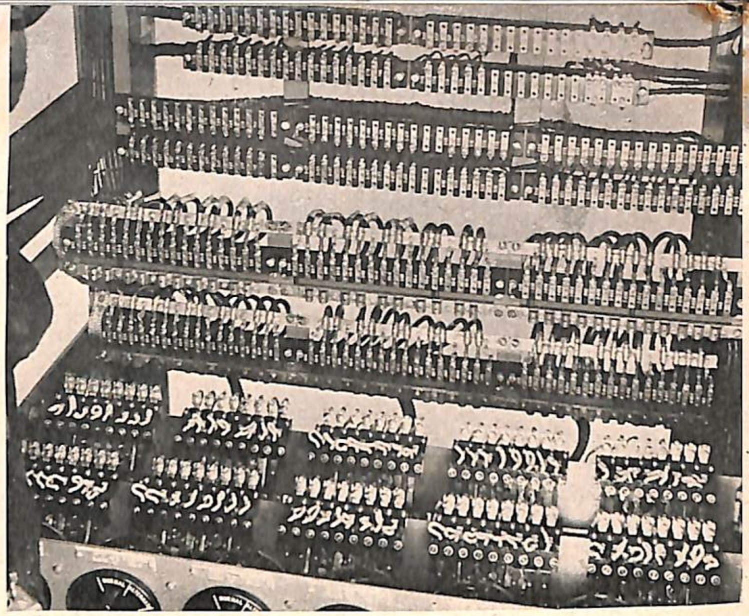
To select the desired radar at the radar repeater location, an *order circuit* is used between the RDS and the repeater. Selection of the system to be displayed is made at the repeater order switch by turning the handle to the radar desired. This causes a light to appear on the RDS at a position on the associated radar selector switch

FIGURE 5—*Simplified schematic wiring diagram of one order circuit and order switch of the type used in the Radar Distribution Switchboard.*





One of the Radar Selector Switch and Output Amplifier Units pulled forward from the face of the Radar Distribution Switchboard. The output cathode follower may be seen in the upper right section of the unit.



Coaxial cable installations in the Radar Distribution Switchboard. Note that each coaxial is stripped back and grounded to a common ground connection, leaving the inner dielectric and conductor free to attach to the appropriate terminal.

corresponding to the position to which the order switch has been turned. The RDS operator then turns the radar selector switch to the position indicated by the light, thus connecting the repeater to the desired radar, simultaneously turning on a light at the repeater order switch and turning out the light at the RDS. The light at the repeater order switch indicates to the radar repeater operator that his order has been carried out. Thus by the use of the switchboard the repeater signals can be selectively fed from five different radars to 20 different radar repeaters by the use of the 20 radar selectors.

Having analyzed briefly the operation of the radar distribution switchboard it may be of interest to review some of the problems encountered in its design.

First the method of remote switching to be employed was given serious consideration. It was mandatory that the system which was to be viewed at a particular repeater be selected at the discretion of the person at the repeater. The method of communicating that choice to the RDS, and the question of manual versus automatic switching at the RDS, had to be solved.

From an operational standpoint it is desirable that telephone communication be used only as a secondary emergency order circuit. It was therefore decided that the switching would be done manually at the switchboard in response to a signal light from the repeater. An order circuit of the type shown in figure 5 (and previously explained) was developed by the Bureau of Ships for this purpose. The system of light signals ties in directly with the other alarm circuits; that is, all fuse alarms and overload circuits are connected so that a visible light indication means that some action is required on the part of the operator. Therefore, with the exception of small red bullseyes to indicate "power on", any other light indicates to the operator that some action is required by him.

The next decision was the determination of the required overall video bandwidth. This was a critical point inasmuch as the video bandwidth determines the fidelity with which the radar signals will be reproduced at the repeaters. The wider bandwidth required of a particular amplifier, the less its gain and therefore the greater the total number of tubes required to achieve the desired overall gain. More tubes mean greater current drain, larger power supply, increased transformer size, etc. Hence a balance was necessary between bandwidth and number of tubes. It was decided to aim at a system which would be at least good enough so that it would not impose a burden on any future repeaters or any radars to be built within a period of approximately five years. On this basis an overall video bandwidth through video drivers and cathode followers of 3 db down at 6 Mc was selected.

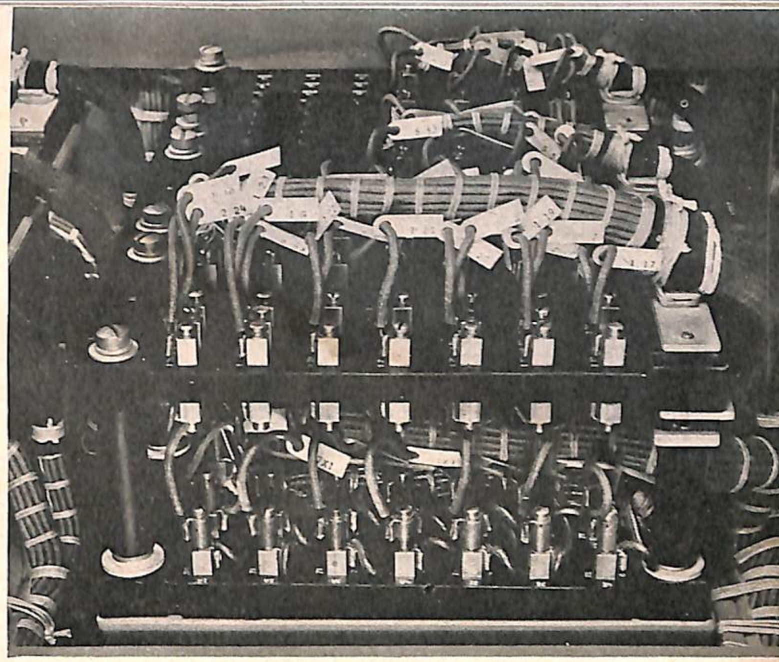
The maximum permissible size, weight and number of tubes also entered in to the question of completeness of isolation required. The present RDS uses, for example, five video drivers, one for each of the radars. It was considered that additional drivers, each driving a fewer number of repeaters, would add such bulk and weight as to overshadow any advantage.

Four power supplies are used for the 20 output amplifiers, each power supply feeding five amplifiers. Thus, if one power supply fails, five repeaters would be disabled. More power supplies would give better isolation and damage protection, but would give increased size and weight. Here again, the advantages and disadvantages were considered, resulting ultimately in the decision to use four power supplies.

Each repeater must be provided with video and trigger input for correct operation. These outputs are furnished by the RDS through the medium of cathode-follower circuits. There are two cathode followers for each repeater, or a total of forty. In this manner each repeater is furnished the necessary video and trigger independent of all other repeaters and it offers the further advantage that these inputs can be terminated directly in each repeater. These cathode followers can be driven by any one of the five radars connected to the RDS by the use of the radar selector switch. In order to maintain the desired bandwidth, the input capacity of the cathode followers had to be kept to an absolute minimum, which made it necessary to locate them as closely as possible to the selector switch. This was accomplished by designing the cathode-follower assembly in such a way that it could be mounted directly on the radar selector.

These cathode followers, in addition to the usual function of isolating the repeater from the switchboard circuits which feed it, permit the transmission of the video and trigger signals via 75-ohm coaxial cable to the radar repeaters. It will be noted that the coaxial cables to and from the RDS are standard RG-12/U 75-ohm cable, whereas the video coaxial cables from driver to radar selectors within the RDS are of 50 ohms. 50 ohms was used within the board to reduce the shunting effects of stray capacity and thus improve bandwidth. The video drivers themselves are conventional low-gain highly-degenerative circuits. They are designed to have a stable 4-volt output across 50 ohms, with sufficient response to maintain bandwidth with as much as 500$\mu\mu$f across the output. This means that repeaters can be switched from one radar circuit to another without affecting either the gain or the response of the system as a whole. In this connection, as explained previously in ELECTRON (page 6, April 1946), at least once a day each video driver should be set so that the output of the RDS is 2 volts peak.

Another design consideration was that of feeding gyro-compass information into the RDS with outputs to 5 radars and 20 repeaters. In order to provide damage control for the gyro-compass circuits, as well as to decrease the load on the gyro bus, there was incorporated in the switchboard system a synchro amplifier which imposed a relatively light load on the gyro bus and permitted a multiplicity of equipment to be tied to its output. Two such synchro amplifiers were provided, one of which could be immediately switched in if the other failed.

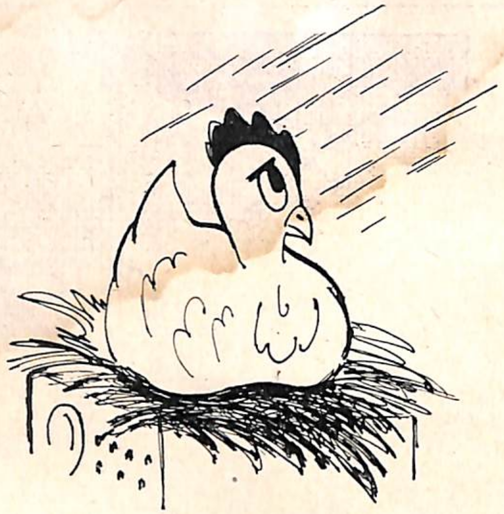


Particular care has been taken in wiring the Radar Distribution Switchboard to insure that all tags are numbered correctly.

In addition to all the above, there were minor considerations as to whether or not built-in test equipment would be desirable, what forms of overload indicators and fuse alarms would be used, etc. For example, it was decided that, because of weight and space requirements, only the vacuum-tube voltmeter would be supplied as built-in test equipment. This instrument is useful not only for setting gain properly, but it will also be noted that its use permits quick spotting of the location of failures and immediate isolation of the radar, repeater, or switchboard component which has failed. This centralization of the servicing problem is one of the advantages of the switchboard.

Good coaxial cable connections were vitally necessary both at the factory and at the installing shipyards. With 20 coaxial cables coming into the RDS (normal and alternate video and trigger from each of five radars) and 40 leaving it (one set of video and trigger to each of 20 repeaters), it was apparent that the success or failure of the RDS might well hinge on the care with which these connections are made.

These are some of the factors that determined the basic components of the system. They then had to be integrated into a unit, giving due thought to the placement of parts and sub-assemblies for ease of operation, accessibility for servicing, ease of installation, reduction of stray capacity, economy of space, etc. The resulting radar distribution switchboard has so far given few indications of failure, and appears to be doing the job for which it was designed.



HEATERS FOR QGA EQUIPMENTS

Page 365 Article 0-33 of the QGA Maintenance Manual states that "An electric heater placed near each slip-ring assembly and bags of silica gel placed in the lower sound room are recommended as preventives against moisture difficulties. A sample heater installation is illustrated in Figure 58."

It has been found that these measures offer little or no protection against moisture collecting on the slip rings. Moreover, late QGA equipments have full-circle slip-ring units instead of the older split type, and are not subject to extensive moisture coating due to seepage.

Accordingly, the two sentences quoted from Article 0-33 and Figure 58 are to be removed from the manual. Heaters presently installed may be left in position provided that no space interference is caused by their presence. Future installation of heaters is not approved.

●

PAINTING SONAR TRANSDUCERS

Special painting methods must be used on certain Sonar transducers used with monitors and tuning indicators. The construction of the CAEK-51095 transducer used with the retractable-dome-type tuning indicator and of the CAEK-51112 transducer used with the Model OCP-1 monitor requires that the end caps of the transducers be soldered to the magnetostriction tube to make the unit leak-proof. However, field reports indicate that corrosion has attacked these soldered joints, causing some failures. In order to minimize this corrosion, the ends of these transducers should be painted with three coats of Americoat-33 (manufactured by the American Pipe and Construction Co., Los Angeles, Calif.) or equivalent, and the painting continued for approximately ½ inch down the magnetostriction tube adjacent to the end caps. Since the acoustic qualities of this paint have not been determined, do not apply it to the entire magnetostriction tube.

The remainder of the magnetostriction tube of the CAEK-51095 transducer should be painted with M-559 anti-fouling paint in accordance with current instructions.

The CQJ-51061 transducers used with the OAX and OCH monitors do not use this soldered construction and therefore do not require the painting with Americoat-33 or equivalent. However, the transducers of the OCH equipment should be painted with anti-fouling paint in accordance with current instructions.

The OCP-1 transducer should be inspected quarterly and the CAEK-51095 and OCH transducers inspected each time the dome is removed in drydock. The paint should be touched up or the units repainted as necessary. Care should be exercised in assembly and installation after painting to prevent damage to the paint coating.

●

CONNECTOR FOR CQA-51080 TRANSDUCER

The Type CQA-51080 transducer is used on submarines as a part of the noise-level monitor, the cavitation indicator and the sonar test target. These transducers were furnished with connectors of two different diameters, ½-inch and ⅜-inch. The pin spacing and length of these connectors is the same, so that the ⅜-inch plug will work in the ½-inch socket. In order to use the ½-inch plug in the ⅜-inch socket, the plug will require turning down, and a new keyway must be cut. There is no polarity to observe when making connections.

It is believed that all transducers were correctly matched with their plugs before shipment. However, difficulty may be encountered when replacing units. If this occurs, it is best to attempt to find a plug of the correct diameter. If none is available, the method of correction just described may be used.

●

CORRECTION TO QJB INSTRUCTION BOOK

Paragraph 25.23 (page 196) of the instruction book for the Model QJB Sonar equipment, NAVSHIPS 900,-238 1B, describes an artificial load to be used to replace the transducer. This load is given as "consisting of 800 ohms shunted by a capacity of 0.41 μf". The capacity to be used should be 0.04 μf. Instead of 0.41 μf.

In figure III-25.7A (page 77) "Equivalent Circuit Element Values", the capacity value should be corrected to read ".03, .04, and .05".

Maximum Permissible Coax Temperatures

■ In planning below-deck installations, cables such as RG-8-9-10-11-12-13/U, RG-14/U, RG-18/U and RG-20/U carrying power up to a few watts may be installed in ambient temperatures as high as 180°F., but these same cables when used as main pulse lines carrying appreciable power must be treated differently. In this connection it is interesting to note that, although present equipments are not using the transmission line at its full permissible average power, the tendency toward increased loading is already strong and new equipments coming into the field are operating at higher power than their predecessors.

To avoid failure of solid-dielectric coaxial lines operating at the full average rated power of the cable, the still-air ambient temperature must not exceed 105°F (40°C). As a general policy, the running of solid-dielectric cables over steam pipes or through uptakes, galleys, laundries, machinery, electrical distribution rooms, and other high ambient temperature spaces should be definitely avoided unless it is known that no hot spots in excess of the permissible maximum will be encountered. Steam pipe lagging alone should not be accepted as affording adequate protection against excessive temperatures. In addition, sufficient air separation should be provided.

Cables transmitting less than full rated power may operate in a higher ambient temperature. A rough rule to follow is that for each 10% below the rated average power capabilities of the cable at which it is being operated, the ambient temperature permitted may be raised 5°F. According to figure 1, the maximum power input to type RG-8/U cable operating at 400 megacycles is 350 watts. Thus, when RG-8/U cable operating at this frequency is used for transmitting only 175 watts of power, it is operating at 50% below its full rated power. The maximum permissible ambient temperature is therefore 130°F, or 25° higher than would be permissible if the cable were operating at its full rated power.

In determining maximum permissible temperatures, consideration should also be given to the fact that the power input end of the coaxial is the end where the maximum internal heat is generated. This is because of the attenuation of the signal as it proceeds along the line (the rate of attenuation depends upon the cable dimensions and frequency) so that the rate of internal heat generation is reduced in each succeeding increment of length. Thus the output end of the cable may be safely installed in an area of higher ambient temperature than the input end. The proper values can be computed from the attenuation constant for a particular frequency and cable type.

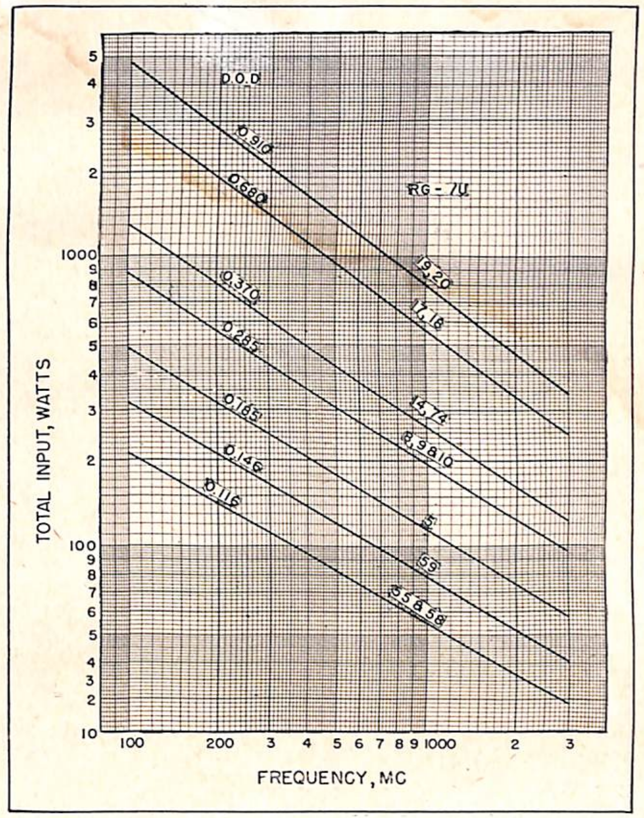


FIGURE 1—*Power rating of standard R-F cables based on inner conductor temperature of 175° and ambient temperature of 104°F.*

TABLE I—Residual Power

DB loss	% residual power	DB loss	% residual power
0.0	100.0	5.5	28.1
0.5	89.4	6.0	25.1
1.0	79.4	6.5	22.3
1.5	70.9	7.0	19.9
2.0	63.3	7.5	17.8
2.5	56.2	8.0	15.9
3.0	50.0	8.5	14.1
3.5	44.6	9.0	12.6
4.0	39.8	9.5	11.2
4.5	35.4	10.0	10.0
5.0	31.6		

For example, assume an RG-20/U cable operating at 350 Mc and average rated power. According to the charts in figures 1 and 2, RG-20/U cable operating at 350 Mc has an average power rating of 1800 watts, and

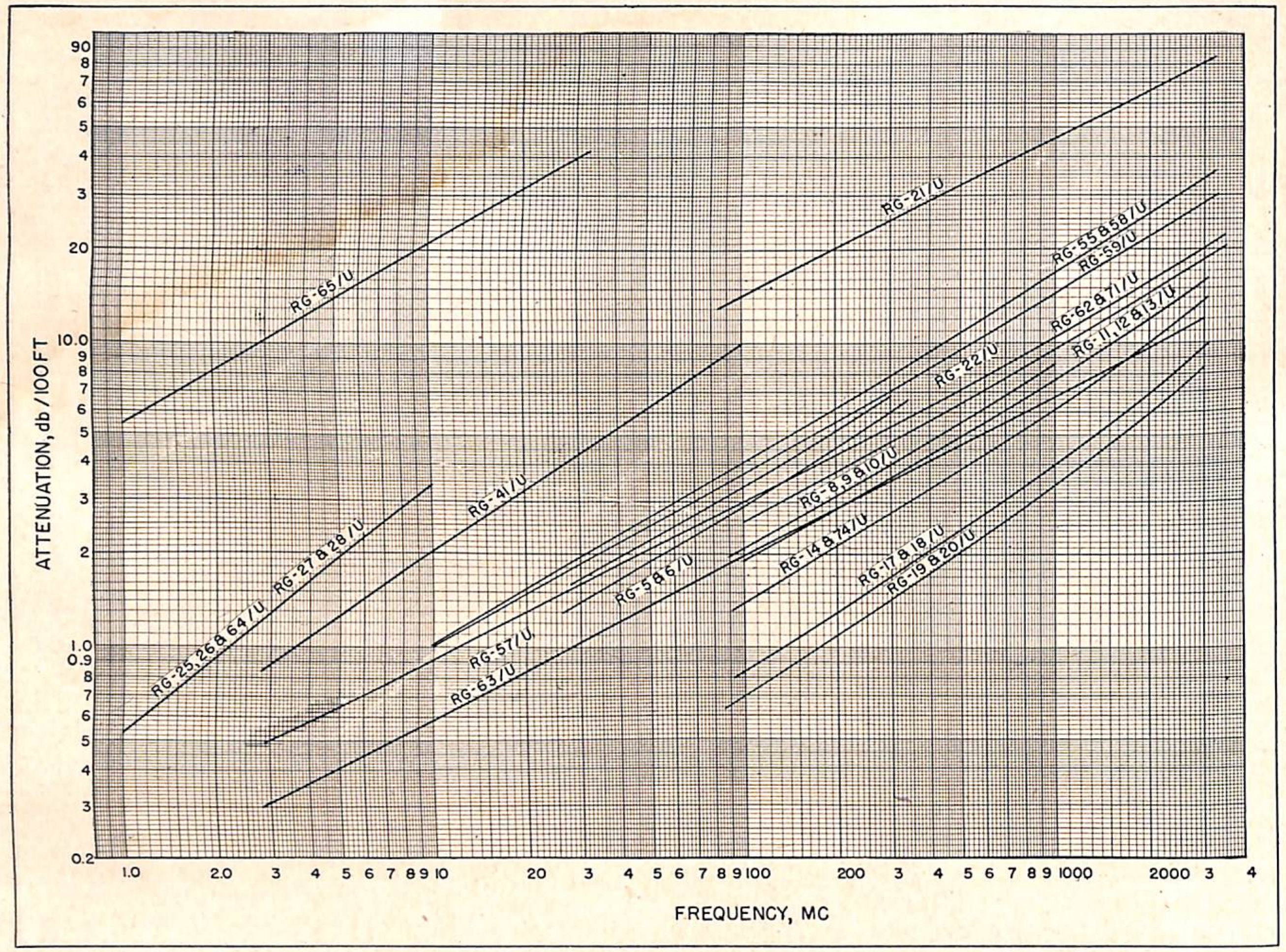
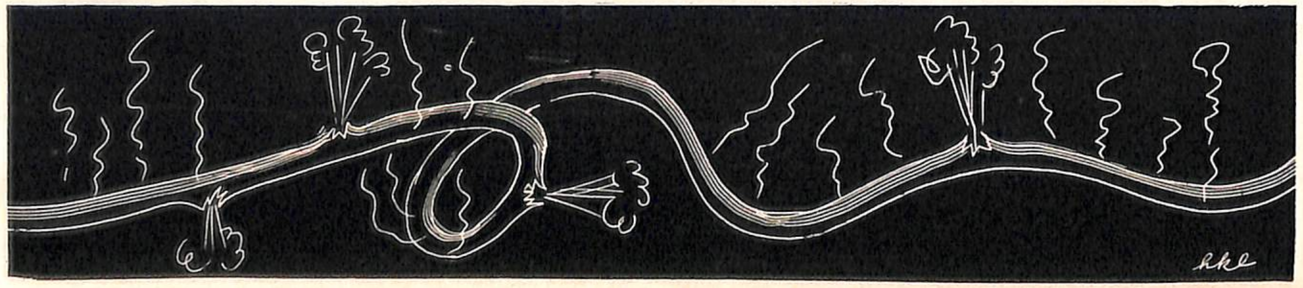
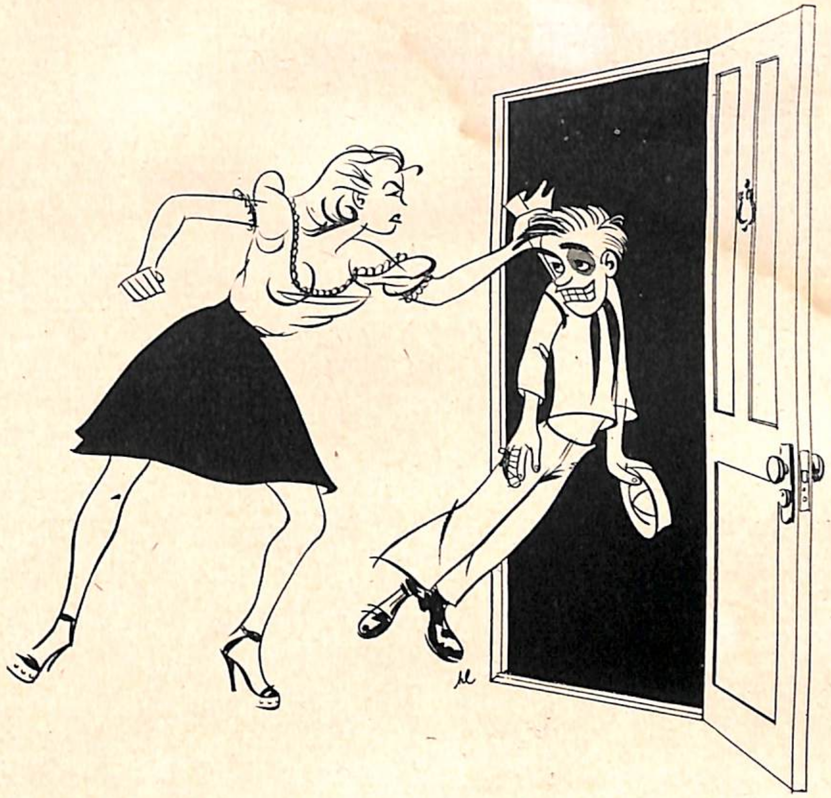


FIGURE 2—*Attenuation in Standard R-F Cables.*

an attenuation factor of 1.6 db per hundred feet of length. Hence, at a point 100 feet along the line, the power has been attenuated to the extent of 1.6 db which, according to table 1, corresponds to a residual power of approximately 69.4% or about 1250 of the original 1800 watts remain. At a point 87 feet further down the line the total loss is 1.6 db × 1.87 = 3 db for the 187 feet. The residual power is now 50% or, in this case, only 900 watts. Applying our rule that the permissible maximum ambient temperature may be raised 5° for each 10% below the average rated power at which the cable is being operated, at a point 187 feet along the line (where the power has dropped 50%) the maximum permissible temperature has been raised 25° so that it can be safely installed in an ambient temperature of 130°F.

The judicious use of the information in this article should result in more direct cable run layouts, thereby reducing their overall length and consequent attenuation in power output. In addition to improving the overall operating efficiency of the system, shorter cable runs will effect some reductions in weight and cost of the wiring installation.





". . . . let him know where he came from and where he is going."

Take Your Pen in Hand

Since its inception ELECTRON *has solicited articles from its readers. It is possibly the first Navy publication to establish the policy of using "by-lines" whereby the author is credited for his work. In spite of this contributions are not coming in as freely as they should. One reason may be that readers are doubtful whether their subjects will be acceptable to the Editors. Another is that people who know what they want to say are afraid to try their hands at writing. It is the purpose of this article to answer both of these objections, and at the same time set forth a few ideas that may be helpful to those who have had only modest experience in writing technical articles.*

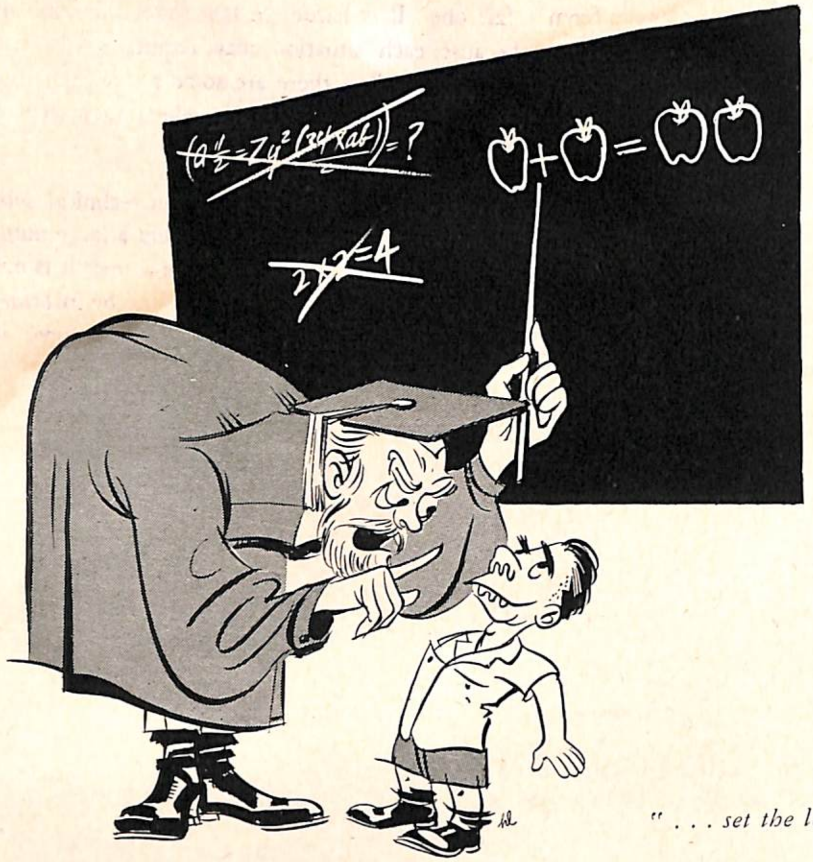
■ No matter how much a man knows, no matter how well he can talk, it is what he writes down that counts the most. For the printed word remains in permanent form to be read and reread. It is for this reason that when a man has something important to say he takes to paper and hopes eventually that the things he writes will be set in type and thus made available to all who are interested.

The readers of ELECTRON have in their hands a medium for permanently recording their work and their ideas. But it is a unique medium, for through it any reader can become an author even though he has almost none of the abilities which one conventionally associates with the writer. ELECTRON is interested in the commonplace, day-to-day matters, important not to a large general group of readers but to its own special audience—the Electronics Technician. ELECTRON needs no sensational subjects to boost its circulation. It requires no fancy writing style. ELECTRON is interested in the story you have to tell. How you tell it is secondary.

So you can become an author. But if you haven't had much experience in writing, a few hints should help. This is particularly true when writing on technical subjects, because technical articles require a special treatment. It is the purpose of this article to discuss a few of the points which should help anyone who has a story to tell, but not too much experience in telling it.

ORGANIZATION AND STYLE

The measure of success in converting thoughts to writing is a combination of organization and style.



" . . . set the level of your explanations."

Organization is putting first things first. Good organization is characterized by a natural and easy flow. As the reader progresses he knows at all times where he is in the story. At any point the author lets him know where he came from and where he is going. Suspense may be a good thing in a detective story, but it has no place in the well-written technical article. The reader who on the last page remarks "Well, I'll be damned" probably hasn't gotten much out of what went before. A little time spent in outlining the entire article will pay off in the end. Only the most experienced writer can sit down with a blank piece of paper and a few ideas, and end up with a finished piece which makes good sense.

Style is the way you put words and sentences together. There's not much you can do about it. You can either write or you can't. Only practice and reading will teach you this art. But on the other hand, it is the least important consideration from this magazine's point of view. If you tell the story clearly and completely, the magazine's editorial staff can fix up the bad sentences. What you have to say is important, how you say it is *not* important.

GOOD JUDGMENT IS IMPORTANT

The most important aspect by far in writing on a technical subject is the attention you pay to clarity. This takes judgment plus a whole lot of ingenuity. Judgment gets its first test when you set the level of your explanations. For the purposes of this magazine, it is proper to assume that the bulk of your readers will be high school graduates with a knowledge of basic radio and electrical theory. Many of ELECTRON's readers are far in advance of this. But no one was ever hurt by reading down. On the other hand, writing at a level above the reader's understanding might as well be in Sanscrit for all the good it will do.

Judgment in writing is not an easy thing to talk about. But here are a few examples of things to do, or not to do.

1—*Use examples.* If you want to say that the current through a fixed resistance varies directly with the voltage applied across the resistance, follow it up with an example; such as "Thus a potential of 110 volts will cause a current of 1.1 amperes to flow through a 100-ohm resistance, while the current will be 2.2 amperes when 220 volts is applied across the resistor."

2—*Don't leave out steps.* In any explanation carry your reader along smoothly from one point to the next. Don't jolt him by leaving out five or six steps. If you have deliberately left out material, say so and explain why (such as, material is found elsewhere, it would take too much space to give the information, it is not clearly known why this happens). There's no bigger gripe than to be struggling along in a not-too-simple explanation and suddenly hit some such statement as "It is obvious that . . . ." Most of the time it isn't obvious, and the odds are the writer wasn't too sure himself.

3—*Say it right the first time.* Did you ever read a lengthy paragraph describing not too clearly the operation of a circuit, and then see it followed up with a second paragraph which starts with "In other words"? Such phrases usually mean "I didn't do so well the first time; I'll try it again". Say it the best way you know how right off the bat, and you won't have to do it over again in "other words".

4—*Be specific.* A sure sign of the lazy writer is the one who uses a lot of vague statements, and leaves the details to your imagination. You will probably recognize these examples of the "hedger". "Now raise the temperature to the desired point"; or "The washers should be of suitable size." The writer in all probability didn't know what temperature, or how big the washers should be, and should have taken the trouble to find out. If the choice really isn't critical and you don't want your reader to go to a lot of trouble to attain needless precision, state this fact very clearly.

All the foregoing points are related to what has been called "judgment". Perhaps it would have been better to call it "common sense", because that's what rings the bell in writing as much as in installation, maintenance, or in cooking *crêpes suzettes.*

INGENUITY PAYS OFF

The ability to think up better ways of telling the same story will normally differentiate a good technical writer from a fair one. It is harder to talk about this kind of ability because each situation may require a different treatment. Nevertheless there are some suggestions that have such universal application to electronics writing that it is worth listing a few of them.

1—*Don't forget tables.* In writing on technical subjects it is not uncommon to have to present a large number of facts and comparative figures. Sometimes it is not apparent that a table can be used to display the information far better than could be done with words alone. It is sometimes a tough job to figure out such a table, but the results are usually worth the effort.

If you wanted to compare the technical features of the TBS and TCS transmitters, you might write down:

TBS: Frequency 60-80 Mc; power output 50 watts; power supply 115 volts, d.c.

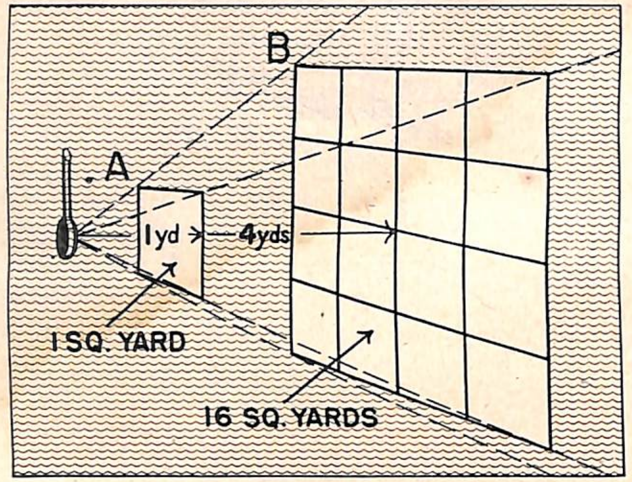
TCS: Frequency 1.5 to 12 Mc; power output 25 watts; power supply 12 volts, d.c.

But the same information would stand out more clearly and be easier to use if you converted it into tabular form:

Characteristics	Model	
	TBS	TCS
Frequency	60-80 Mc	1.5-12 Mc
Power output	50 w	25 w
Power supply	115 v, d.c.	12 v, d.c.

2—*Use of illustrations.* By far the hardest test of the writer's ingenuity lies in the selection of illustrations. Even the simplest article is usually improved by well-chosen illustrative material. Even if words alone will

"you will recognize . . . the hedger."



". . . the sound passing through one square yard at A is spread thinly over sixteen square yards at B, if B is four yards from the projector."

tell your story, don't forget the appeal that pictures carry for the average reader. No matter how well a piece is written, no matter how practical its applications, it might as well not be printed if no one reads it. Photographs help achieve this reader-appeal. If you are writing on a subject that doesn't require illustration, think over the possibilities of a few pictures. Try and get local photographic facilities to make some shots for you. Including people in pictures of this kind increases their interest. In any event photographs specifically taken to illustrate a story are always better than stuff picked from a file as an afterthought.

When to use an illustration cannot be set down by any simple set of rules. Sometimes the story cries out for obvious pictures; it is almost impossible to make your meaning clear without them. If you wanted to tell what a circle is, you might say it is *the locus of all points in a plane equidistant from a fixed point,* but you would almost assuredly use a picture to show what a circle looks like.

Perhaps a less-obvious example would be an attempt to explain that intensity of projected sound varies inversely as the square of the range. Here we would use both an example and an illustration.

Thus the sound passing through one square yard at A is spread thinly over sixteen square yards at B, if B is four yards from the projector.

You don't have to be an artist when you write for ELECTRON. A rough sketch will enable the art staff of the magazine to prepare the necessary final product suitable for publishing. And here a word of caution. Don't mess up a good photograph with badly lettered legends and arrows. Instead, make a rough sketch of the photograph on another piece of paper and indicate on it what lettering is to go where. Do not trace over the photographs, as any slight embossing of the surface of the photograph will show when printed. Glossy photographs are best.

3—*Schematic diagrams.* Schematic diagrams are so often used in all kinds of technical articles on electronics subjects that a special word is in order. In most cases schematics intended for publication will be redrawn, so that it isn't too important to receive them in final smooth form. But it does help if they are carefully laid out. The sequence of the parts and stages should follow in a logical order.

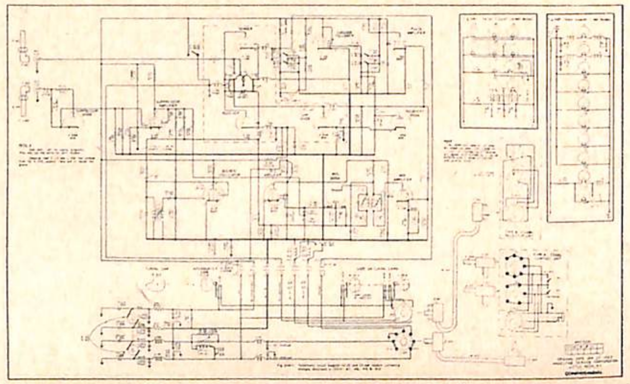
Many articles are written involving modifications to existing circuits. Don't throw an entire modified schematic at your reader and expect him to be able to find the half dozen circuit changes that you have made. It's not much easier than finding a needle in a haystack. Rather isolate that part of the schematic that has been changed, and then indicate what connections you have removed and what has been added. This is not only clearer to understand, but is a much better guide to the man who must actually make the change in his equipment.

DON'T BE AFRAID TO TRY

The foregoing ideas will make writing easier. But the important thing to remember is that what ELECTRON wants is *contributions.* How they are written or in what form they are sent in is distinctly secondary. Your Commanding Officer will be glad to forward what you write. He won't worry about the details of how it is written, how illustrated, or even if it is technically perfect. He'll let the Bureau of Ships worry about these non-essential details.

So try your hand at writing an article. You'll get a kick out of seeing your work and name in print.

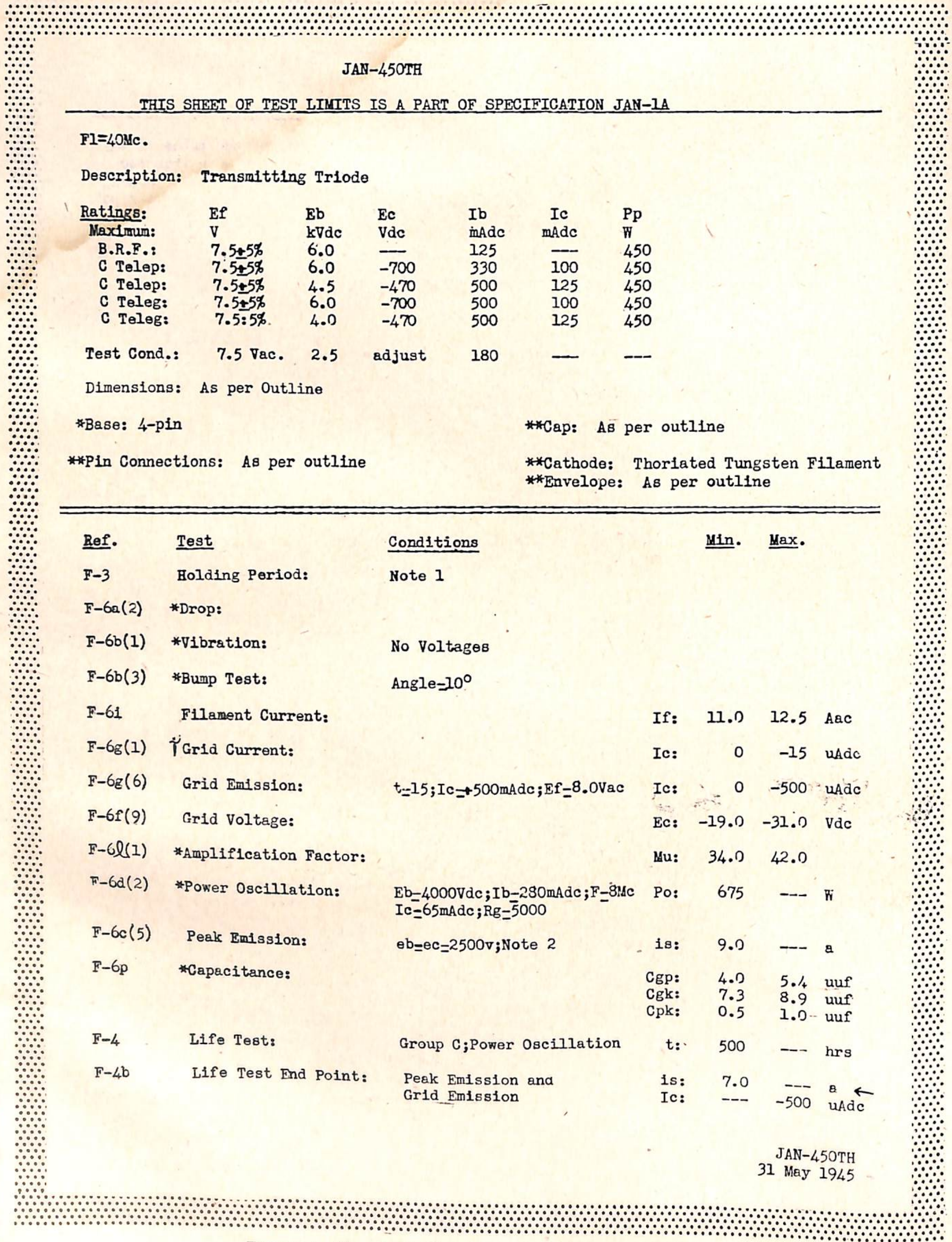
". . . find the half-dozen circuit changes you have made."



Electrical Test Unit. This unit is arranged to apply nearly every conceivable electrical test to which a transmitting tube may be subjected.

Electron Tube Testing

■ During the war we were able to enjoy the advantages of good electron tube performance, and it is now appropriate to give credit where it is due. The Joint Army-Navy Electron Tube Committee and the tube manufacturers are responsible for the rigorous tests to which the tubes are subjected, and therefore deserve a large share of the credit. They set the test limits which describe a tube of acceptable quality, and wrote the manual which contains the test specifications covering all tubes purchased for military use. This manual, The Joint Army-Navy Specification JAN-1A for Electron Tubes, is the tube manufacturer's and electronic manufacturer's "bible". It not only covers the two major objectives of tube testing, which are to determine whether a new tube has characteristics which will enable it to replace directly tubes of the same type previously produced, and to attempt to ascertain whether the tube has a life expectancy in excess of the minimum guarantee, but also sets up tests to determine the ability of the tube to stand up under adverse conditions.



JAN-450TH

THIS SHEET OF TEST LIMITS IS A PART OF SPECIFICATION JAN-1A

Fl=40Mc.

Description: Transmitting Triode

Ratings:	Ef	Eb	Ec	Ib	Ic	Pp
Maximum:	V	kVdc	Vdc	mAdc	mAdc	W
B.R.F.:	7.5±5%	6.0	---	125	---	450
C Telep:	7.5±5%	6.0	-700	330	100	450
C Telep:	7.5±5%	4.5	-470	500	125	450
C Teleg:	7.5±5%	6.0	-700	500	100	450
C Teleg:	7.5:5%	4.0	-470	500	125	450
Test Cond.:	7.5 Vac.	2.5	adjust	180	---	---

Dimensions: As per Outline

*Base: 4-pin

**Cap: As per outline

**Pin Connections: As per outline

**Cathode: Thoriated Tungsten Filament

**Envelope: As per outline

Ref.	Test	Conditions		Min.	Max.	
F-3	Holding Period:	Note 1				
F-6a(2)	*Drop:					
F-6b(1)	*Vibration:	No Voltages				
F-6b(3)	*Bump Test:	Angle=10°				
F-6i	Filament Current:		If:	11.0	12.5	Aac
F-6g(1)	†Grid Current:		Ic:	0	-15	uAdc
F-6g(6)	Grid Emission:	t=15;Ic=+500mAdc;Ef=8.0Vac	Ic:	0	-500	uAdc
F-6f(9)	Grid Voltage:		Ec:	-19.0	-31.0	Vdc
F-6ℓ(1)	*Amplification Factor:		Mu:	34.0	42.0	
F-6d(2)	*Power Oscillation:	Eb=4000Vdc;Ib=280mAdc;F=8Mc Ic=65mAdc;Rg=5000	Po:	675	---	W
F-6c(5)	Peak Emission:	eb=ec=2500v;Note 2	is:	9.0	---	a
F-6p	*Capacitance:		Cgp:	4.0	5.4	uuf
			Cgk:	7.3	8.9	uuf
			Cpk:	0.5	1.0	uuf
F-4	Life Test:	Group C;Power Oscillation	t:	500	---	hrs
F-4b	Life Test End Point:	Peak Emission and Grid Emission	is: Ic:	7.0 ---	--- -500	a ← uAdc

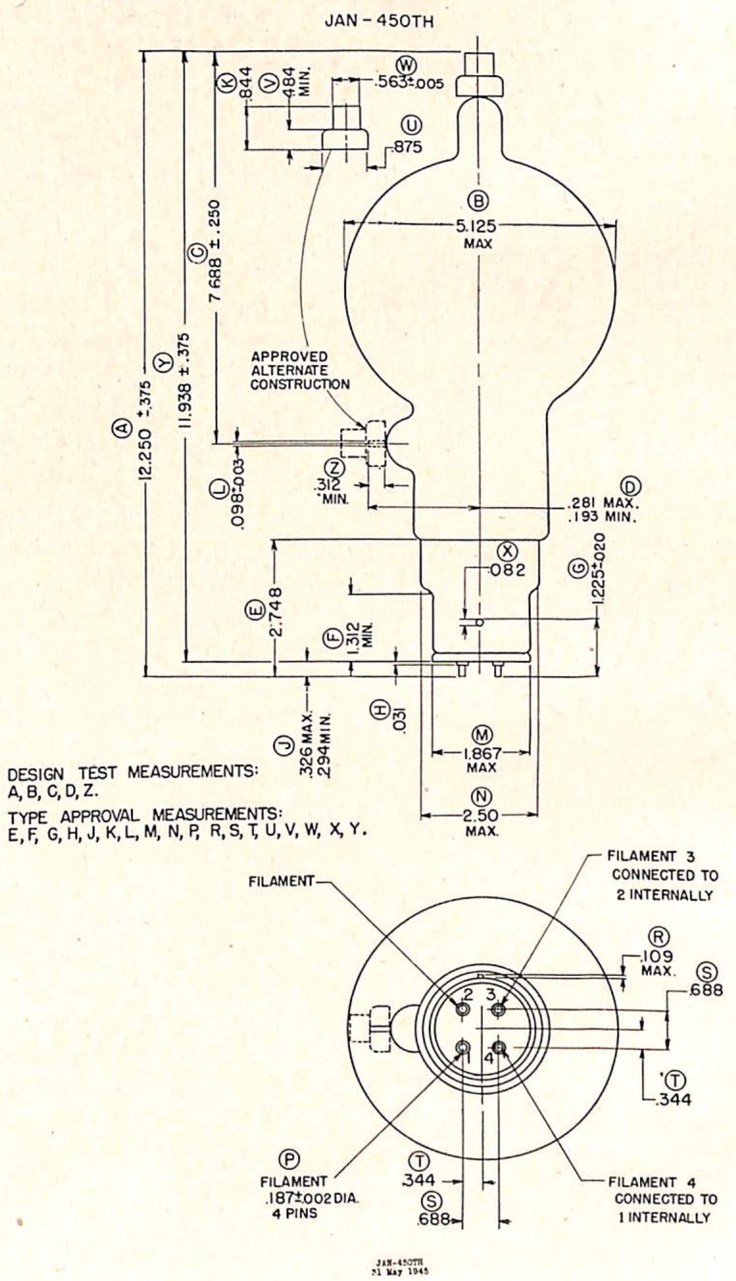
JAN-450TH
31 May 1945

FIGURE 1—*Test Limit Sheet for 450TH Transmitting Tube.*

JAN-450TH

Note 1. In addition to the 24 hour holding period, ten percent of the tubes in any production lot shall be held for a period of 72 hours. If more than two percent of the tubes fail to meet the limits specified in the test marked with a "dagger" sign, the tubes represented by this sample shall be subject to recall and all tubes shall be held for a period of 72 hours.

Note 2: Voltage shall be applied in pulses such that the tube will not be damaged.



JAN-450TH
31 May 1945

FIGURE 2—*Outline drawing for type 450TH (Notes 1 and 2 are those referred to on the Test Limit Sheet, Figure 1).*

Using the 450TH as a typical example of the tests for transmitting tubes, test-limit and tube-outline drawings for the 450TH have been reproduced from the JAN-1A specifications, in figures 1 and 2 respectively, and will be used in an analysis of the test procedure. The accompanying photographs showing factory shots of Eimac 450TH tubes under test were provided by Eitel-McCullough Inc.

Above the double line on the test limit sheet is given the descriptive matter relating to the tube, and maximum ratings under certain operating conditions. Also listed above the double line are the test conditions under which nearly all the tests are to be made, and certain mechanical requirements the tube must meet. The latter requirements are those preceded by a double asterisk (**) and are determined by "Type Approval" tests performed at a government laboratory. F1 is the maximum frequency (40 Mc for 450TH) at which maximum plate voltages and plate input must be reduced.

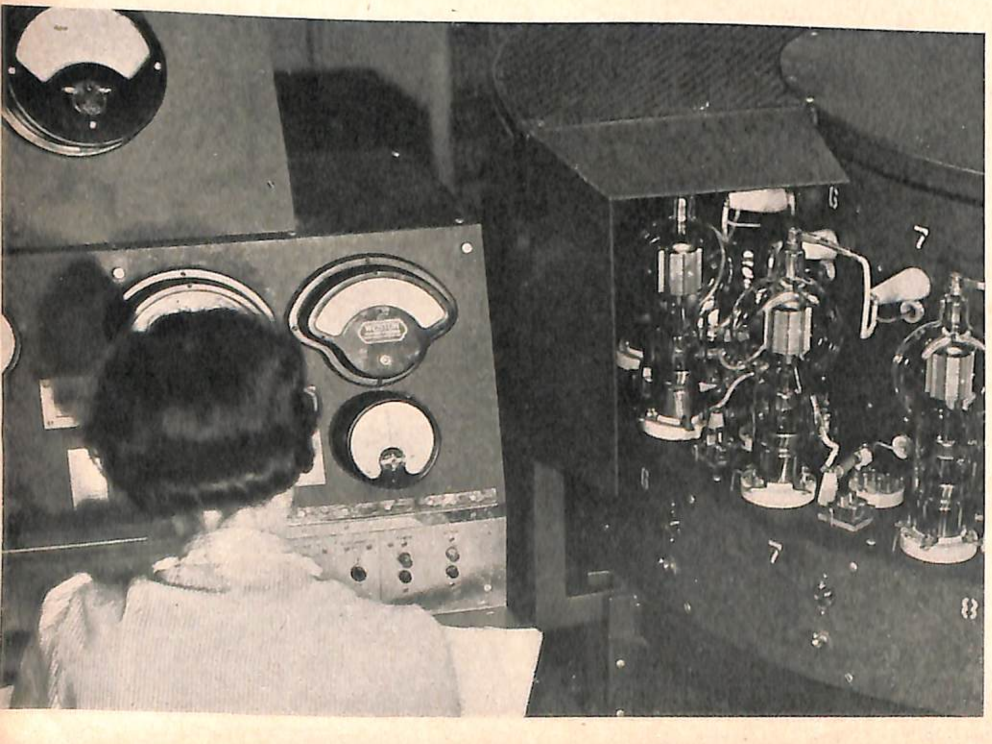
Below the double line are given minimum required tests which each tube must pass to meet military requirements, plus additional "design" tests, preceded by a single asterisk (*), which are to be made on a certain percentage of the tubes.

The first column below the double line, titled "Ref." refers to the basic section of the JAN-1A in which are listed the basic requirements of the test, defining such things as type of test equipment and duration of test. These tests for the 450TH are given below. Column two merely names the tests. Column three gives the condition under which the test is to be made, if these differ from the "Test Conditions" given above the double line. Column four gives the minimum and maximum values which define an acceptable tube under the specified conditions.

Minimum required tests to which a 450TH is submitted are as follows:

F-3. *Holding Period:* Unless otherwise specified, tubes shall be held without operation for a minimum period of 24 hours after the completion of all manufacturing processes. The tests indicated by a dagger (†) on the tube specifications sheet shall be made at the conclusion of this period. Other required tests may be made before or after the "Holding Period". The tests indicated by a dagger (†) may be eliminated on tube types requiring a holding period of 24 hours provided that: (1) a check of all production tests is made after the holding period on a 10 percent sample (not less than 100 tubes of any lot), (2) the manufacturer has previously made all tests specified except life test, and, (3) all tubes having shorts, discontinuities and air leaks are eliminated before packing the tubes. All production tests shall be applied to all tubes if more than 2 per cent of the sample tubes fail to meet the test limits.

F-6a(2). *Carton Drop Test:* Each tube shall be packaged and packed as for shipment and the packed shipping cartons shall be dropped four times (once on their tops and bottoms and once on each of two adjacent sides) from a height of three feet above a rigid surface. This test may be waived on any order where tests have been previously made to the satisfaction of the inspector on the same type of tubes packed in the same type of cartons. Later a packing specification (JAN-P-75) was written which defined the type of packing to use.



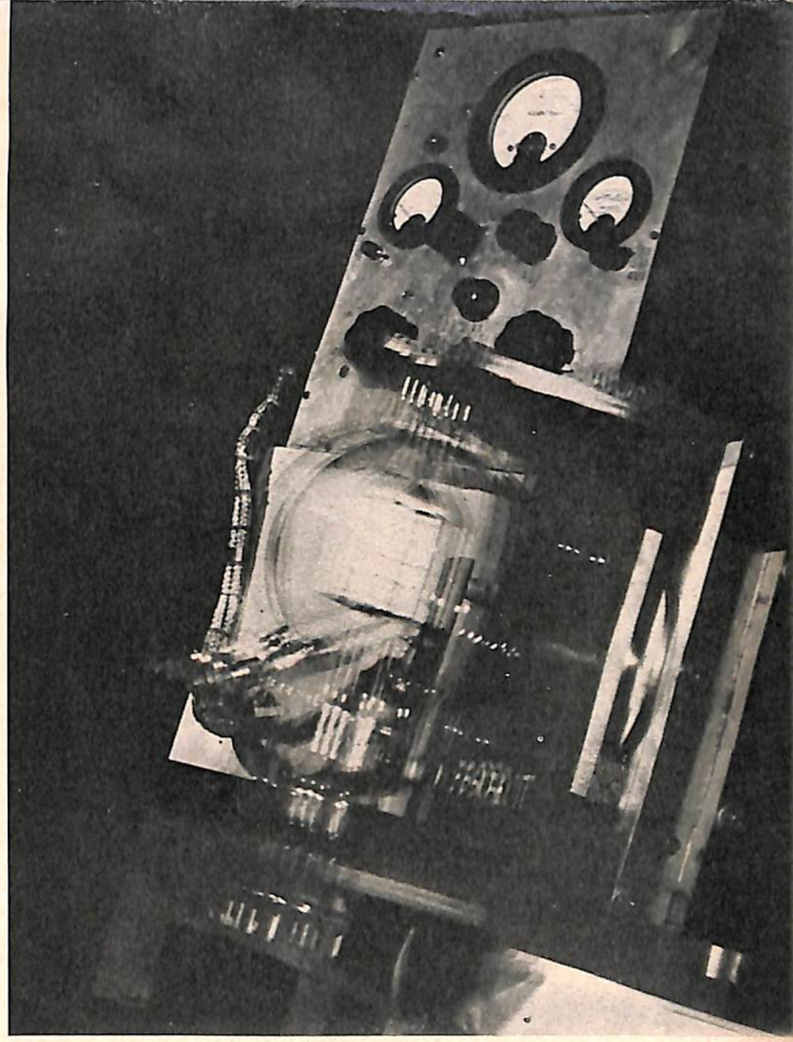
◀ *Rotating Test Unit. This unit is used for measuring grid bias required to give specified value of plate current at specified plate voltage, and for measuring grid current under the same conditions.*

F-6b(1). *Vibration* — Method A: Each tube to be tested shall be mounted rigidly on a platform which is capable of being vibrated with simple harmonic motion of 0.04-inch amplitude (total movement of 0.08 inch). Each tube shall be vibrated for one minute over a frequency range from 12 to 25 c.p.s. in a direction normal to the plane cutting the tube elements at their greatest cross section. The tube shall then be vibrated for one minute over the same frequency range in a direction parallel to the plane cutting the elements of the tube at their greatest cross-section, and perpendicular to the axis of the elements. For tubes which have cylindrically-shaped elements, two positions shall be chosen which are 90° apart, one of which, due to the geometrical arrangement of the element supports, should produce maximum displacement of the elements. When this test becomes a production test, the time shall be that necessary to obtain a stable reading.

F-6b(3). *Bump Test:* Each tube to be tested shall be mounted in a vertical position in the standard bump-test equipment. The hammer arm shall be released from the specified angle and allowed to strike the glass envelope at an angle of 45° to the plane of the press seal. The hammer shall strike the tube in a position such that free pendulum motion is obtained without excessive wobble. This procedure shall be repeated three times. Subsequent to this test, the elements of the tube shall show no significant dislocation, the tubes shall be inspected to insure compliance with all the requirements of mechanical assembly, and the results of all the tests shall be within the limits on the tube specification sheet. If the first 10 tubes successfully pass this test, the test may be waived on the balance of the selected tubes, at the discretion of the Government inspector.

F6i. *Heater or Filament Current:* The specified voltage shall be applied to the heater or filament. Current shall then be within the limits specified. During this test no other elements shall be conducting.

F6d(2). *Power Oscillation Test:* When the frequency of operation is not specified, each tube shall be operated in a self-oscillatory circuit, or as a separately-excited amplifier, at any frequency not in excess of F1. If an oscillatory frequency is specified, the test frequency shall not be less than that value but may be above if the manufacturer desires. Unless otherwise specified, the plate voltage and plate input current shall be the value specified under the rating for class-C telegraphy; the load circuit being adjusted to obtain not more than the specified plate input current and the grid excitation being adjusted until the grid direct current is within 20 per cent of the value specified under "Oscillation Test". A resistor of the specified value (10 per cent tolerance) shall be connected in series with the grid circuit. Under these conditions the total (not "useful") radio-frequency plate power output of the tube shall be within the limits specified or, for separately excited circuit, shall exceed the minimum limit by at least the amount of the driving power, and the tube shall operate satisfactorily without sign of gas discharge or other injury. In the case of tubes having a rated plate dissipation in excess of 150 watts, the duration of this test shall be five minutes. However, oscillation tests conducted on "Type Approval" samples may be continued for one hour.



Vibration Test Unit. This unit simulates the vibrations to which a tube must be subjected before it can be passed for military use.

F-6f(9). *Grid Voltage:* With the specified potentials applied, the grid voltage necessary for the conduction of the specified current shall be within the limits on the tube specification sheet.

F-6g(1). *Total Grid Current:* With the specified voltages applied to the tube, the total grid current read with a series microammeter (the total external circuit resistance not exceeding 100,000 ohms) shall be within the limits specified. The duration of this test (including preheating time at specified test conditions, if continuous with the test), shall be 2 minutes unless a greater duration is specified or, in the case of tubes having a specified maximum current of 5 microamperes or less, it shall be only long enough to establish a steady value. When a greater duration is required, a test period of 3 minutes will be permitted if the grid current at the end of this time is stable, is no longer rising, and does not exceed the limit specified. (Note: t is test duration in seconds unless otherwise specified.)

F-6g(6). *Primary Grid Emmission:* By means of a suitable rectifier and 60-cycle a-c source, the grid shall be

Aging Rack. The tubes are placed in this rack and power is applied. This process ages the tubes before they are subjected to the tests set up on the Test Limit Sheet.

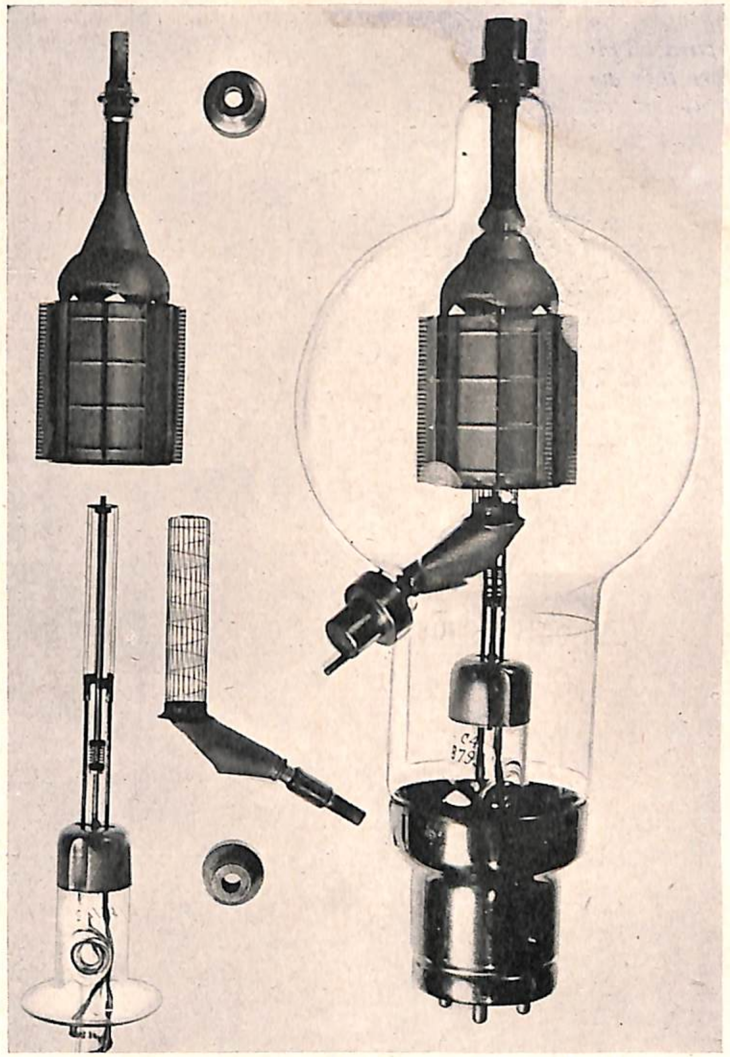
heated during the positive half cycles and the presence of primary emission measured during the negative half cycles. The voltage shall be adjusted for the average grid current specified on the tube specification sheet. The primary emission current shall be not greater than the limit specified.

F-61(1). *Amplification Factor:* The amplification factor of tubes shall be measured by any method detailed in the 1938 Report of the Standards Committee of the Institute of Radio Engineers, or equivalent method, and shall be within the limits specified.

F-6c(5). *Peak Emission:* The filament or heater potential shall be applied, and the grid or grids if present shall be connected to the plate. A suitable capacitor charged to the specified potential shall be discharged through the tube and a load resistor. The peak current shall be measured by an oscilloscope suitably calibrated. An equivalent method may be used. There shall be no evidence of sparking during the latter half of this test, and the peak current shall be within the specified limits.

F-6p. *Capacitance:* The grid-cathode capacitance (Cgk), plate-cathode capacitance (Cpk), grid-plate capacitance (Cgp), and any other specified inter-electrode capacitances, shall be measured with the cathode cold and with no direct voltage present. The vacuum tube shall be in its complete form with its base or with its leads. The tube pins and leads shall be shielded from each other and from other elements of the tube so that they and their connections shall not form part of the capacitance being measured. Unless otherwise specified capacitances shall be measured with standard tube shield or metal envelope connected to cathode. Transmitting tubes with bulbs larger than ST-16 shall be measured without a shield, as will smaller transmitting tubes if their ratings specifically prohibit operation with a shield. Tubes read with or without an external shield shall have connected to cathode all external metal parts integral with the tube and not at terminal potential. Such parts are lock-in tube bases, metal base shells pins with no connection, etc. When capacitance measurements are made on indirectly-heated tubes the heater shall be connected to the cathode unless in special cases the measurement is between the cathode only and other elements, or the heater and other elements. For vacuum tubes having elements other than a control grid, a plate, and a cathode, the additional elements of the active section including internal shields shall be connected to the filament or cathode by the shortest possible connections. For a multiplex tube structure all elements of the other section(s) shall be grounded except when reading inter-section coupling capacitances. In general, grid-plate capacitance measurements shall be made with all other parts of the tube structure grounded, input capacitance measurements between the control grid and all other parts of the tube structure with the plate grounded, and output capacitance between the plate and all other parts of the tube structure with the grid grounded. The measurements shall be made by any of the methods described in the 1938 Report of the Standards Committee of the Institute of Radio Engineers or by an equivalent method as exemplified by the direct-capacitance high-frequency bridge-type circuit or the direct-capacitance high-frequency transmission-type circuit, as shown by RMA Standards Proposal No. 140 dated April 27, 1943. On transmitting tube types employing a metal sleeve type base the capacitance measurements shall be made without grounding that sleeve.

F-4. *Life Tests:* Tubes to be furnished without a service life guarantee shall be subjected to life tests, under the conditions specified on the tube specification sheet, throughout the production of the order, in accordance with paragraphs F-4a, F-4b, and F-4c of this specification, and records of test data shall be reviewed by the inspector. Tests may be run intermittently or continuously at the option of the manufacturer unless otherwise specified.



The 450TH Transmitting Tube—View on the left shows the three elements before assembly.

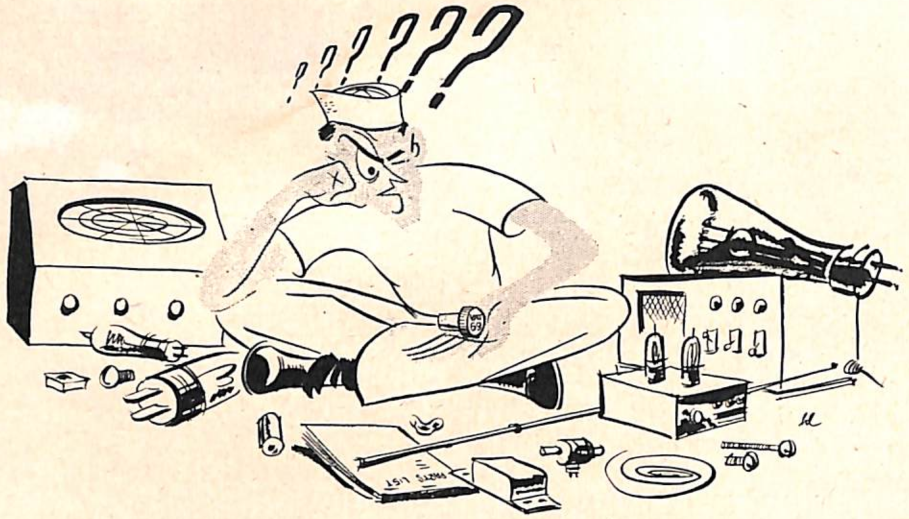
F-4b. *Life-Test End Point:* The criterion for life-test end point shall be that tube characteristic specified on the tube specification sheet, and a tube shall have reached the end of its life when the limits specified for that characteristic have first been reached when measured under specified test conditions. Where two or more tests are specified for Life Test End Point, failure of any one of these tests shall constitute failure of the tube. When optional tests are specified on the tube specification sheet, that one selected by the manufacturer at the start of the test shall govern. Tubes shall be life tested under the conditions specified on the tube specification sheet.

A variation of 10 per cent of the rated electrode potentials, except for filament or heater voltage, shall be permissable provided the dissipation is maintained.

When a new production run is started, the inspector may release for shipment after satisfactory completion of 50% of the number of hours specified for life tests. In the event of continuous production and on the basis of preceding satisfactory life tests, tubes may be accepted even though the life tests from that particular lot have not been completed.

At the conclusion of the time specified for life test, the average life of the tubes placed on test shall not be less than 80% of the number of hours specified. If this percentage is not attained, all tubes represented by the samples shall be rejected subject to negotiation. The life of each tube shall be determined by adding to the hours of life at the last life-test-end-point passing test of the tube; either 10 per cent of the hours specified as the minimum life, or ½ the hours between the last life-test-end-point passing test and the life-test-end-point failure test, whichever value is smaller.

While the foregoing analysis covers only the tests specified for a 450TH transmitting tube it is hoped that it also points out the extent of the work accomplished by the Joint Army-Navy Electron Tube Committee, in setting up the JAN-1A Specifications.



Spare Parts Terminology

■ Various interpretations of the nomenclature for Electronic Spares cause no end of confusion to all activities concerned. All electronics personnel should be familiar with the correct terminology, and should use it in all applicable correspondence, dispatches, requisitions, inventories, etc. The following outline will assist in properly identifying electronic spares for radio, radar, sonar, and fire-control radar *(Mark)* equipments.

TABLE I—Radio, Radar and Sonar Spares

Correct Designation	Often Referred to as	Usage
Equipment Spares	Individual, Operating, Station, Mobile, Ship or Primary Spares.	Equipment Spares are issued with equipments to all using activities.
Extra Equipment Spares	(no equivalent)	These are exact duplicates of Equipment Spares and are issued to vessels to replace spares lost by fire, water or battle damage.
Tender Spares	Base	Issued to tenders, repair ships and some special-service vessels.
Stock Spares	Bulk, Navy Yard Secondary or Depot Spares	Issued to Navy yards and advance bases or other stocking activities for replenishment of Equipment and Tender Spares.
*Supplementary Spares (for Equipment, Tender or Stock Spares)	Different List Spares	Issued to Navy yards and other stocking activities for issue to vessels.

TABLE II—Fire-Control (Mark) Equipment

Correct Designation	Often Referred to as	Usage
List "A" Spares	(no equivalent)	Consists of replacements for parts most liable to failure, less vacuum tubes. (Each equipment is supplied with List "A" Spares and one spare set of vacuum tubes).
List "B" Spares	(no equivalent)	Replacement for parts not commonly subject to failure, issued to vessels having stowage space to carry these parts. (One set of List "B" Spares will normally maintain four or more fire control radar equipments.) None of the List "B" Spares are incorporated in the List "A" Spares.
List "C" Spares	Drawer or Unit Spares	This type consists of complete replacement units of an equipment, supplied to vessels having stowage space to carry these parts. One List "C" Spares usually is sufficient to service one equipment.
List "D" Spares	Bulk "A" Spares	Supplied to shore fire control radar maintenance activities. Contains the same items in the same quantities as List "A" Spares. (Packed in wooden cases.)
List "E" Spares	Bulk "B" Spares	Supplied to shore fire control radar maintenance activities. Contains the same items in the same quantities as List "B" Spares. (Packed in wooden cases.)

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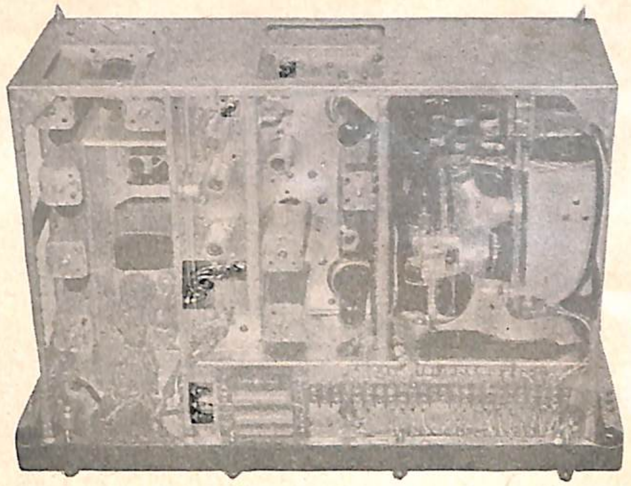
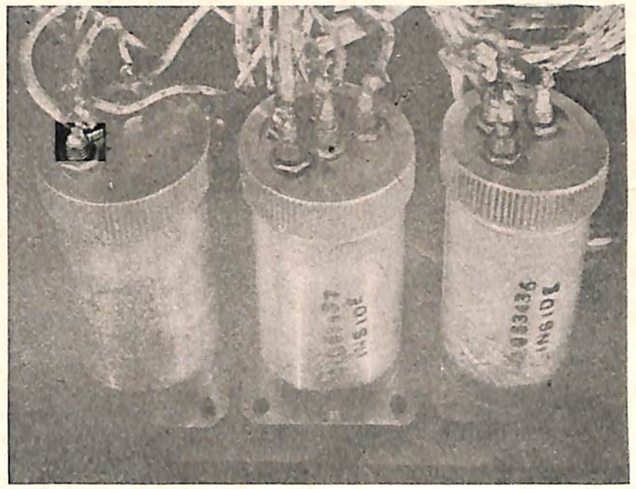
* Supplementary Spares are sets made up of types and quantities of spare parts called for in RE 13A 730 series of spare parts specifications, but not called for in the earlier major equipment specifications issued prior to the inauguration of these specifications.

Ceramic Capacitors in MAR Radio Equipments

■ Here we introduce a very small item with a very large name. It is the titanium oxide ceramic-insulated feed-through capacitor. This component is the latest version of our old friend the by-pass capacitor and provides a simple, efficient method of effecting a by-pass to ground when passing through a chassis or metal can. The assembly closely resembles a ceramic lead-through or stand-off insulator and consists of a silvered ceramic capacitor tube having the outside electrode soldered to a plated bushing and the inside electrode firmly connected to the feed-through material. It has heavy terminals, large contact areas, a high resonant frequency which is well above the MAR range and, being of the feed-through type, practically eliminates lead inductance to ground. Because of these features it has been incorporated into some of the MAR radio equipment circuits and has proved to be very satisfactory. Unfortunately it is inherently fragile and has suffered considerable damage. Ceramic insulators have been cracked or broken and the thin plated inner electrodes have been melted. These troubles, which were caused both by the use of excessive heat and pressure while soldering and by careless gripping or tightening of the assemblies while installing or removing, have either placed the equipment out of operation or in a state of reduced operating efficiency. A few simple precautions could have prevented this trouble, so it is recommended that all personnel engaged in the repair and maintenance of electronic equipment familiarize themselves with this type of capacitor and see that proper care is exercised in the future. The accompanying photographs should be an aid to the technicians as they show specific applications in the MAR radio equipment.

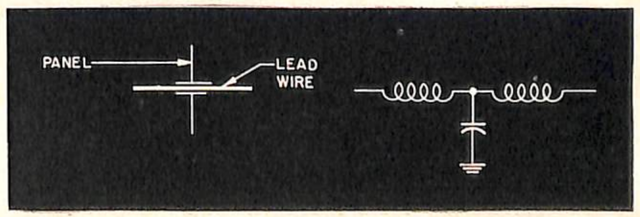


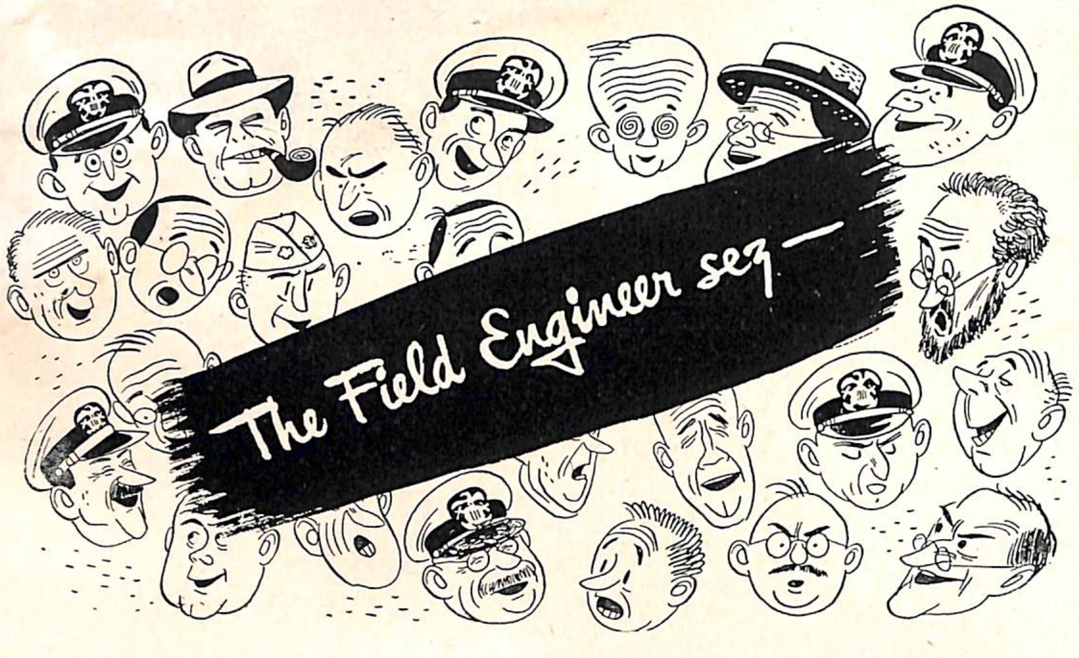
Transmitter-Receiver of the MAR equipment, showing the location of some of the concentric ceramic capacitors.



Concentric ceramic capacitors contained in the power supply unit. Note that one of the capacitors is damaged.

Schematic of the feed-through capacitor (left) and its equivalent circuit (right) showing that the device functions as a "T-type" low-pass filter. The leads and feed-through wire furnish the inductance, and the concentric coatings on the shell furnish the capacity. ▶





OPEN PULSE CABLE IN SG-4X

A report has been received concerning trouble in the SG-4X installation on the *Franklin D. Roosevelt* which may prove enlightening to other technicians maintaining SG-3 or SG-4X equipments. The indication was a sudden decrease in response until no targets could be picked up beyond one mile. Routine changing of T-R tube and magnetron plus check of receiver failed to correct the trouble. A check of waveforms showed that the modulator unit was operating normally.

The pulse cable was next checked with a megger, and it read open while it was still connected to the pulse transformer. The cable was removed from the pulse transformer with extreme difficulty and the cause of trouble became readily apparent. The outer conductor of the plug was badly corroded as though by acid or salt water, and the inner conductor was almost entirely eaten away, apparently by arcing. In addition to these two troubles, the porcelain insulator was broken. There was also evidence of poor assembly between the plug and cable, the soldered joints being poorly finished. When a new plug was attached to the cable plus installation of a new pulse transformer, the equipment returned to proper operation.

—E.F.S.G.

TUBE CHANGES IN THE SG-3

The phantastron range circuit in the SG-3 employs a 6SA7GT tube. A recent failure in this circuit emphasized a point which is of importance to all technicians. If it becomes necessary to replace V-602 in the SG-3 it must be replaced with a 6SA7GT, as a 6SA7 metal tube will not work in this application. Technicians who are charged with maintaining these equipments should mark the socket in some manner to preclude other technicians making this mistake in future maintenance of the equipment. Raytheon Manufacturing Company is marking all current production of this equipment in such a manner.

—E.F.S.G.

HOW GOOD ARE YOUR TUBES?

The entire WFA submarine sonar equipment aboard the USS *Odax* (SS-484) was checked to determine the cause of its poor performance. The chief trouble was found to be poor tubes throughout the system.

The tube situation aboard this ship is an acute problem. All the spare tubes were tested and less than ten percent of them could be called satisfactory. None could be called excellent. Of all the tubes tested, none came up to the transconductance rating called for by the tube tester. Different tube testers were used to determine whether the fault was with the testers or the tubes, but it proved to be the tubes. The only tubes that gave good results were those of the ruggedized "W" type.

After finally placing a good set of tubes in the equipment, the WFA behaved excellently. In the future, great care should be exercised to place only those tubes in the equipment that test satisfactorily. Although it is sometimes necessary to run through a dozen tubes to get one good one, the results obtained from the equipment when good tubes are installed make this extra work worth while.

As a result of this experience, the *Odax* has started a regular tube checking procedure both for new tubes and tubes in the equipment. A similar procedure is recommended for all ships.

—E.F.S.G.

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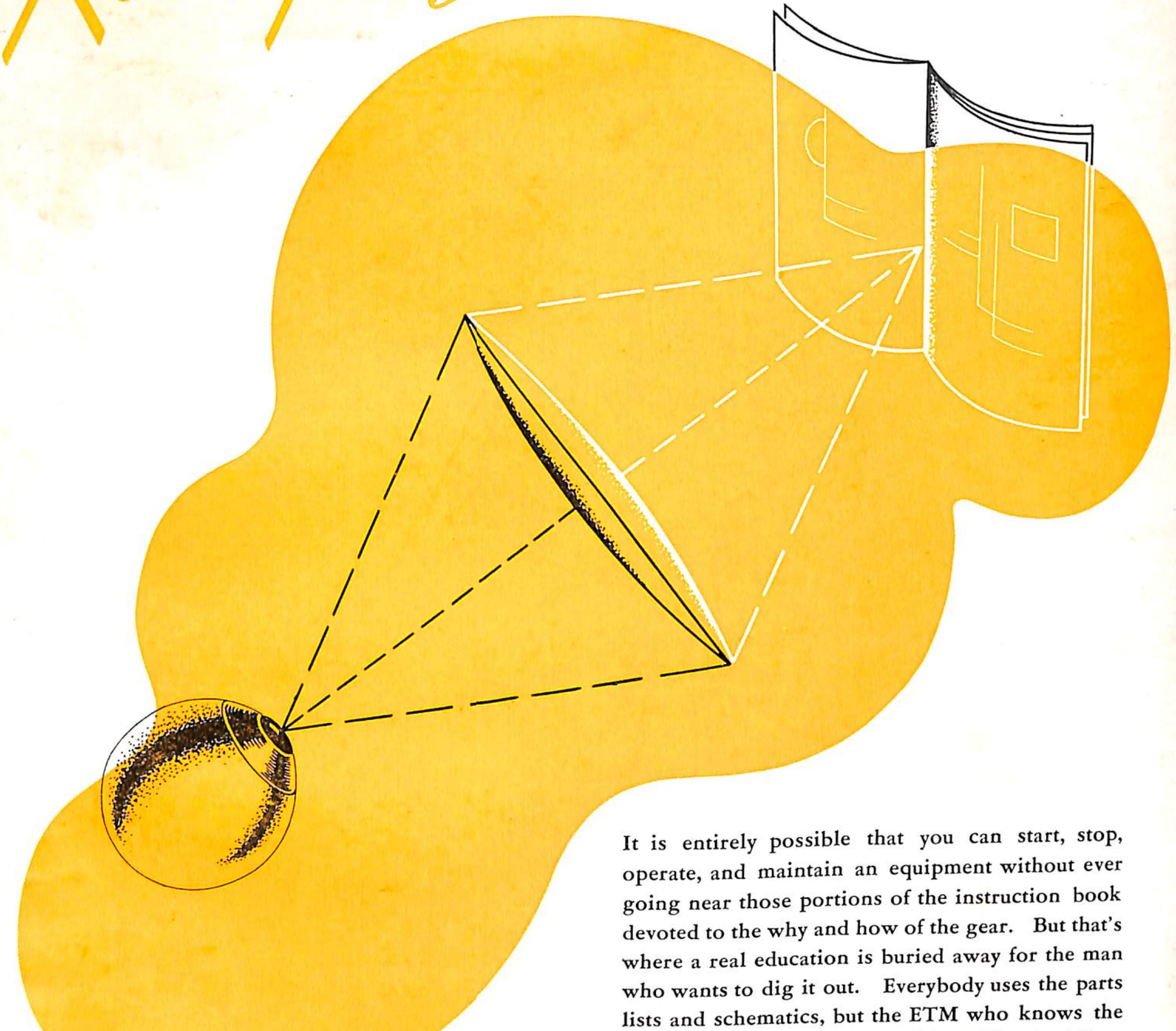

It is entirely possible that you can start, stop, operate, and maintain an equipment without ever going near those portions of the instruction book devoted to the why and how of the gear. But that's where a real education is buried away for the man who wants to dig it out. Everybody uses the parts lists and schematics, but the ETM who knows the theory of the circuits he is working with—the fellow who knows why a resistor is where it is—is much more likely to get at the source of obstinate trouble than one who doesn't. So study your instruction books whenever you have time to spare.

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